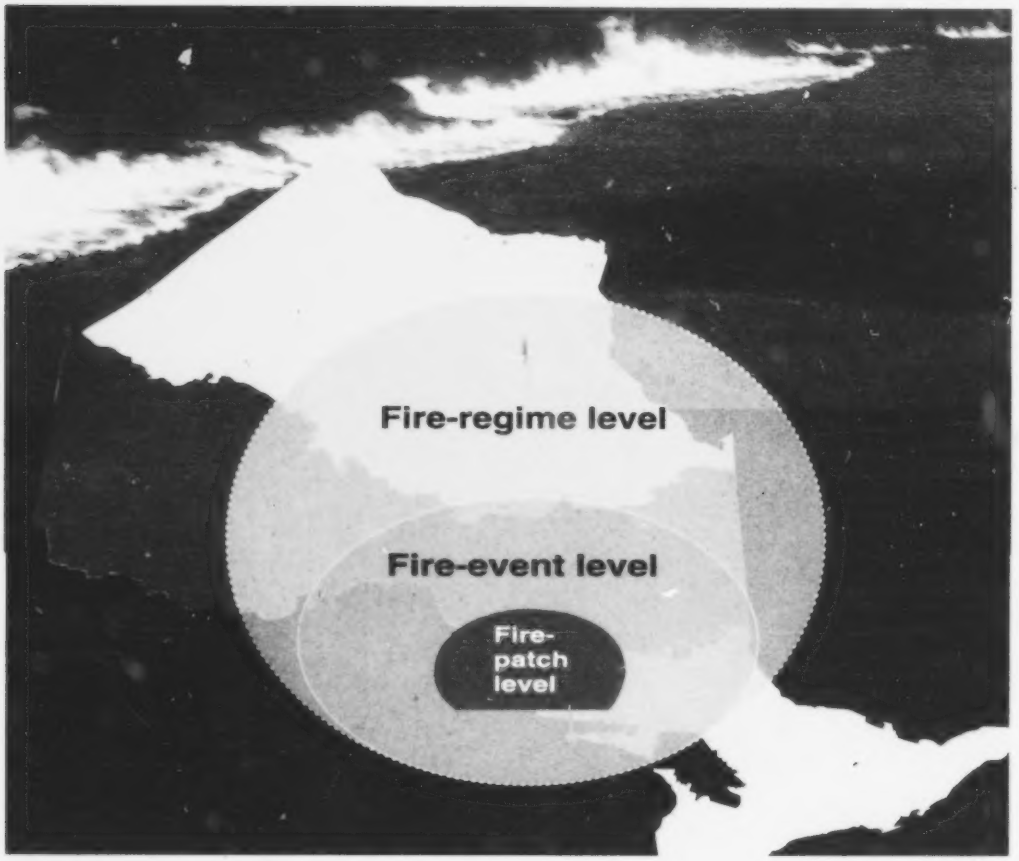
Forest Research Information Paper 164

Multiple-Scale Research Studies on Boreal Forest Fire Regimes to Inform Ontario's Policies for Emulating Natural Forest Disturbances

A Prospectus



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Multiple-Scale Research Studies on Boreal Forest Fire Regimes to Inform Ontario's Policies for Emulating Natural Forest Disturbances

A Prospectus

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Abstract

A clear understanding of forest fire regimes is essential for emulating natural disturbances in forest management. This prospectus presents a broad framework for a series of research studies to investigate Ontario boreal forest fire regime at multiple scales. The broad research goal is to reduce uncertainties in knowledge about boreal forest fire regimes related to policy directions in MNR's Forest Management Guide for Natural Disturbance Pattern Emulation (NDPE). This goal will be accomplished by establishing the state of the knowledge by reviewing and synthesizing published literature, determining the characteristics of the broad-scale fire regime in boreal Ontario through simulation modelling, and understanding the extent and spatial patterns of post-fire residuals using mapping and monitoring. In addition to reducing scientific uncertainties in NDPE guide directions, these studies will advance knowledge to inform future forest management policies and practices as well as other research on forest fires and emulating natural disturbances.

Resumé

Projets de recherches à échelles multiples portant sur les régimes des feux pour mieux documenter les politiques de l'Ontario en matière de reproduction des perturbations naturelles dans la forêt boréale : un prospectus

Il est essentiel de comprendre clairement les régimes des feux de forêt si l'on veut reproduire les perturbations naturelles en aménagement forestier. Ce prospectus présente un vaste cadre de travail voué à une série de projets de recherches à échelles multiples visant l'étude des régimes des feux dans la forêt boréale de l'Ontario. Le but étendu de cette recherche est de réduire les incertitudes dans la connaissance des régimes des feux dans la forêt boréale en rapport avec les orientations des politiques du Guide for Natural Disturbance Pattern Emulation - NDPE (guide de reproduction des perturbations naturelles) du MRN. Pour atteindre cet objectif il faut d'abord établir l'état des connaissances en effectuant la révision et la synthèse des recherches publiées à ce jour, en définissant les caractéristiques d'un régime des feux à large échelle dans la forêt boréale de l'Ontario par la modélisation de la reproduction, et en comprenant mieux l'étendue des résidus après un incendie de forêt et leur configuration spatiale, par le biais de la cartographie et du suivi. En plus de réduire les incertitudes scientifiques quant aux orientations du guide NPDE, ces études font avancer les connaissances à l'appui des politiques et des pratiques d'aménagement forestier, de même que les autres recherches sur les feux de forêt et la reproduction ou l'émulation des perturbations naturelles.

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Introduction

Knowledge of fire regimes and emulating natural forest disturbances

Broad-scale allogenic disturbances, such as fire, pest epidemics, windthrow, and flooding, are considered natural and are intrinsic elements of some forest ecosystems. Since these disturbances have been occurring for millennia and have periodically altered forest composition, structure, and processes, it is logical to assume that such forest systems have evolved and adapted to withstand the effects of periodic disturbances. These systems continue to exist in the midst of the impacts of *natural* disturbance, because the degree of disturbance does not exceed the inherent resilience capacity of the forest system, thereby providing an implicit measure of self-sustainability of that ecological system. This reasoning has provided the basis for the paradigm of emulating natural forest disturbances (ENFD) as a surrogate for ensuring sustainability in forest management and a coarse filter for conserving biodiversity (Hunter 1990, Attiwill 1994). The rationale for ENFD is that human intervention within the limits of natural disturbances (i.e., system resilience) ensures sustainability. ENFD is a conservative approach in the absence of a clear and unequivocal definition of forest sustainability. In addition, natural disturbances provide an effective benchmark or a null hypothesis to assess forest management practices (Perera and Buse 2004). The debate about what is a *natural disturbance* (given centuries of human intervention in forest patterns and processes) notwithstanding, characterizing disturbance regimes with minimal human influence is an essential step in attempting to emulate those (Suffling and Perera 2004).

Since forest disturbances occur at many spatial and temporal scales, those characterizations will be many and varied; nor is it possible to completely and perfectly characterize disturbance regimes. However, adequate science knowledge is an important prerequisite for practicing ENFD:

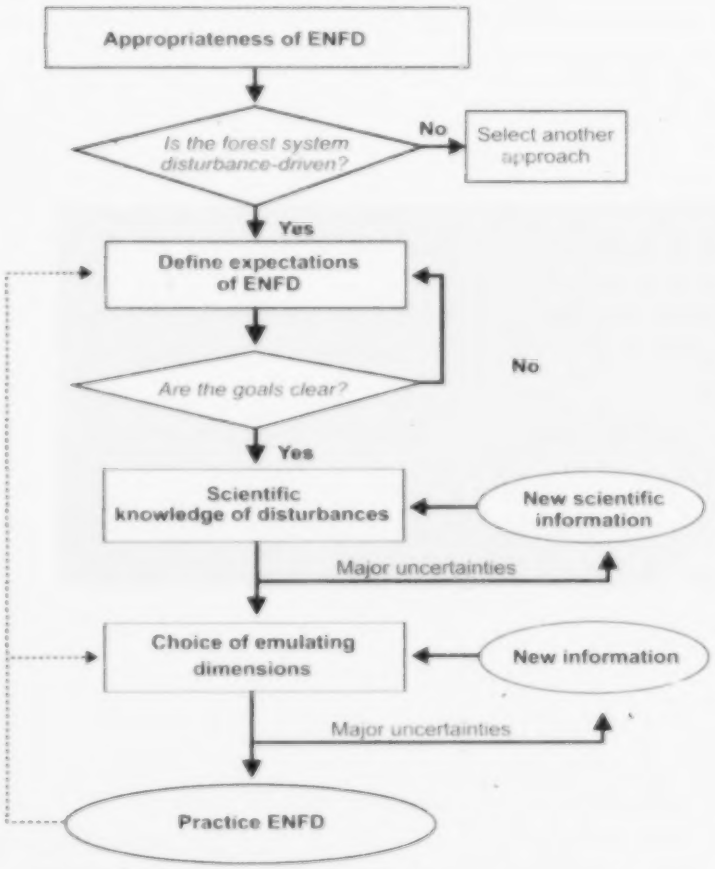

Figure 1. *Schematic guidelines for forest practitioners to emulate natural forest disturbances, highlighting the importance of the adequacy of science knowledge, in particular the disturbances, as a prerequisite for practicing ENFD (adapted from Perera et al. 2004a).*

After deciding its appropriateness and associated expectations, practitioners must ensure that they have sufficient knowledge of the disturbances they intend to emulate (Figure 1). This raises the question of how to estimate the degree of adequacy of scientific knowledge. One approach is to assess the *uncertainty* of the knowledge: If the uncertainty is low, the knowledge is more adequate and, therefore, more reliable. If scientific knowledge is deemed uncertain, those uncertainties must be addressed and reduced before proceeding towards the specific practices of ENFD, which are goal based (Perera et al. 2004a).

The Ontario Ministry of Natural Resources (MNR) had produced a *Forest Management Guide For Natural Disturbance Pattern Emulation* (NDPE guide; OMNR 2002) to provide policy direction for designing harvest patterns. Ecological scientific uncertainties of all the major directions in the guide were identified recently, based on a systematic review of published literature on natural fire disturbances (Perera et al. 2004b). To reduce these uncertainties, a series of multi-scale scientific studies was initiated in 2005, as proposed in the *Action Plan for Scientific Studies to Assess the Effectiveness of the Directions in the Forest Management Guide for Natural Disturbance Pattern Emulation* (OMNR 2004; Appendix I), to improve the understanding of characteristics of natural fire regimes in Ontario's fire-driven landscapes.

Reducing uncertainty can have several meanings, for example, *reducing ambiguity* inherent in terms and concepts associated with emulating natural forest disturbances to improve clarity of intent, goals, and actions. This reduction in ambiguity can be achieved by developing unequivocal definitions for terms and lucid explanations of concepts and applications. As well, reducing uncertainty in knowledge can be accomplished by discerning what we do and don't know, to improve certainty of what is known. In science, improving certainty is typically accomplished by *following the scientific method* – applying explicit, repeatable, and logical methods to address what is not known – to ensure reliable results, and whenever possible, *formulating clearly-stated hypotheses* based on current knowledge and testing those explicitly – so that science is progressively advanced.

This prospectus presents the scientific rationale and approaches for multi-scale studies to reduce uncertainties in understanding boreal forest fire regimes in Ontario. It provides a brief description of the study goals, methods, expected deliverables, and interlinkages as well as the resources and timeframe that determine their practical scope.

Research goals and objectives

The overall research goal is to identify the major uncertainties in knowledge of natural fire disturbances in Ontario's boreal forests and reduce those by applying appropriate scientific methods at multiple scales. At the *broad scale*, we attempt to understand the characteristics of fire regimes and at a relatively *finer scale*, we attempt to elucidate the occurrence of post-fire residuals. As a working premise for this study, we assume *natural* fire disturbances to be those that are not suppressed by human activities.

Specific objectives:

To meet the overall goal, specific objectives for understanding characteristics of fire regimes at a broad scale are to examine:

- The spatial, temporal, and random variability in forest fire size distribution in boreal Ontario; for example:
  What is the likelihood of specific fire disturbance patch size classes and the shape of the size-class distribution curve?
  Does the shape of the size-class distribution curve change through time?
- The spatial and random variability in fire frequency of occurrence in boreal Ontario; for example:
  What is the likelihood of fire disturbance patches overlapping in time and space?
  Are smaller patches likely to be closer to one another than larger patches?
- Understand the broader-scale regionality in fire regime as an emergent property of Ontario's geo-climatic patterns; for example:
  Does the likelihood of fire disturbance patch size classes vary, and can this variation be explained based on geography or climate differences?

Specific objectives for understanding the response of forest cover to fire behaviour at finer scale are to examine:

- The spatial geometry and variability of the continuum in post-fire residuals (from trees to patches) within fire events in boreal Ontario; for example:
  What is the extent of post-fire residual structure and its distribution?
  Is the above affected by fire disturbance patch size?
- The early temporal dynamics of post-fire tree residuals within fire events in boreal Ontario; for example:
  How long does residual structure persist following burns?
- The causal factors of occurrence and spatial patterns and variability in post-fire residuals (from trees to patches) within fire events in boreal Ontario; for example:
  Is residual structure more likely to occur near or on certain site features within fire disturbances?
  Is residual structure influenced by pre-fire structure and composition?

The outcome will be reduced uncertainty about Ontario's boreal forest fire disturbance regime with respect to the NDPE guide (OMNR 2002) directions (Table 1). Specifically, knowledge of fire regime at broad scale will be more certain, particularly that related to fire size distribution, spatial occurrence of fire events, and fire return intervals, as well as spatio-temporal heterogeneity and stochasticity. In addition, knowledge of post-fire residuals – occurrence, spatio-temporal variability, and causal factors – will be more certain. As a result, remaining uncertainties and gaps in knowledge of forest fire disturbance will be evident, and specific hypotheses can be proposed to address them.

Table 1. *How the scientific studies address uncertainties associated with the NDPE guide's directions.*

Specific NDPE guide (OMNR 2002) directions	How these studies will address uncertainty associated with directions
Clearcut size distribution: • Boreal – 80% cuts <260 ha • Great Lakes-St. Lawrence – 90% of cuts <260 ha	• By reducing uncertainty in the knowledge of spatial, temporal, and random variability in forest fire size distribution, more reliable ecological knowledge will be available to design policy directions for harvest size-class distributions • By elucidating intrinsic regionality in fire regime characteristics, policy directions can be stratified across the province using sound and relevant ecological basis
Spatial separation of harvest patches: • New clearcuts must be separated by intervening forest that is minimum 3 m in height or 20 years of age • <260 ha cuts separated by minimum 200 m; for every additional 100 ha, separation distance increases by 50 m	• By understanding spatial and random variability in fire frequency of occurrence, more reliable ecological knowledge will be available to design policy directions for spatial arrangement of harvest patches
Area of residual patches: • 2-8% insular • 8-28% peninsular	• By characterizing the spatial geometry and variability in post-fire residuals, more reliable ecological knowledge will be available to design policy directions for retaining forest cover as a continuum during harvest • By understanding the causal factors of occurrence and spatial patterns and variability in post-fire residuals, more reliable ecological knowledge will be available to design policy directions for spatial arrangement and category of post-harvest residuals
Number of residual trees: • 25 well-spaced trees per ha; of these 6 to be live, large diameter based on species fire tolerance	

Research Overview

Research studies are grouped into three categories:

a) ***Reviews and syntheses of published literature*** on boreal fire regimes (specifically fire size distribution) and post-fire residuals at the patch and tree levels. The focus is to establish the state of scientific knowledge in literature, guided by a series of hierarchical questions, and to identify significant knowledge gaps.

b) ***Determining the characteristics of the broad-scale fire regime in boreal Ontario*** by improving spatial simulation modelling capability. The focus is develop means to reliably, objectively, and repeatably estimate stochasticity and spatio-temporal heterogeneity of size-class distribution, spatial tendency of occurrence, and return interval of natural (lightning caused and unsuppressed) forest fires.

c) ***Spatial mapping and monitoring*** of post-fire residuals at the patch and tree levels within natural fire events (lightning caused and unsuppressed). The focus is to empirically estimate heterogeneity of the residual continuum from patches to trees and to understand potential causal factors of spatial variability, as well as the temporal dynamics of the tree-level residuals.

These studies also follow a spectrum of spatio-temporal scales. The simulation studies are conducted at broad regional scales (millions of hectares) at coarse resolution (1 hectare) to understand long term (several centuries) fire regime properties. The spatial residual mapping studies are conducted at fire event-scale (one fire at a time), at fine resolution (couple of square metres), and for short time periods (few years). Figure 2 presents linkages among the studies.

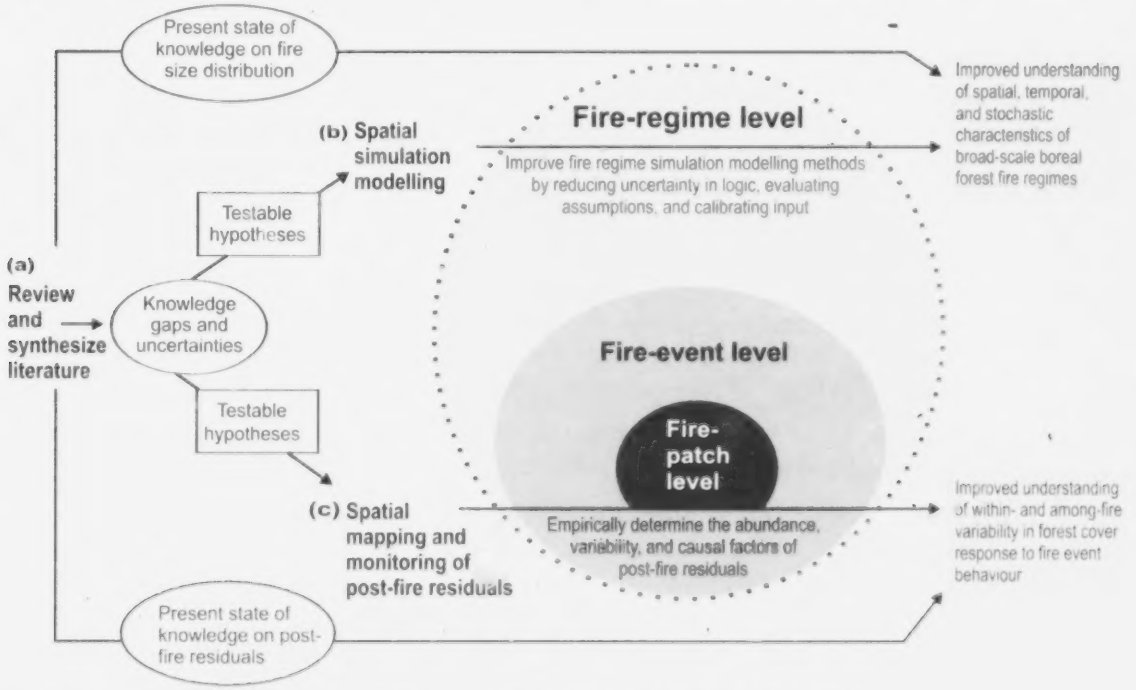
Present state of knowledge on fire size distribution
Improved understanding of spatial, temporal, and stochastic characteristics of broad-scale boreal forest fire regimes
(b) Spatial simulation modelling
Fire-regime level
Improve fire regime simulation modelling methods by reducing uncertainty in logic, evaluating assumptions, and calibrating input
Testable hypotheses
(a) Review and synthesize literature
Knowledge gaps and uncertainties
Fire-event level
Testable hypotheses
Fire-patch level
(c) Spatial mapping and monitoring of post-fire residuals
Empirically determine the abundance, variability, and causal factors of post-fire residuals
Improved understanding of within- and among-fire variability in forest cover response to fire event behaviour
Present state of knowledge on post-fire residuals

Figure 2. *Focus and scale of planned research studies on boreal forest fire regimes and their linkages.*

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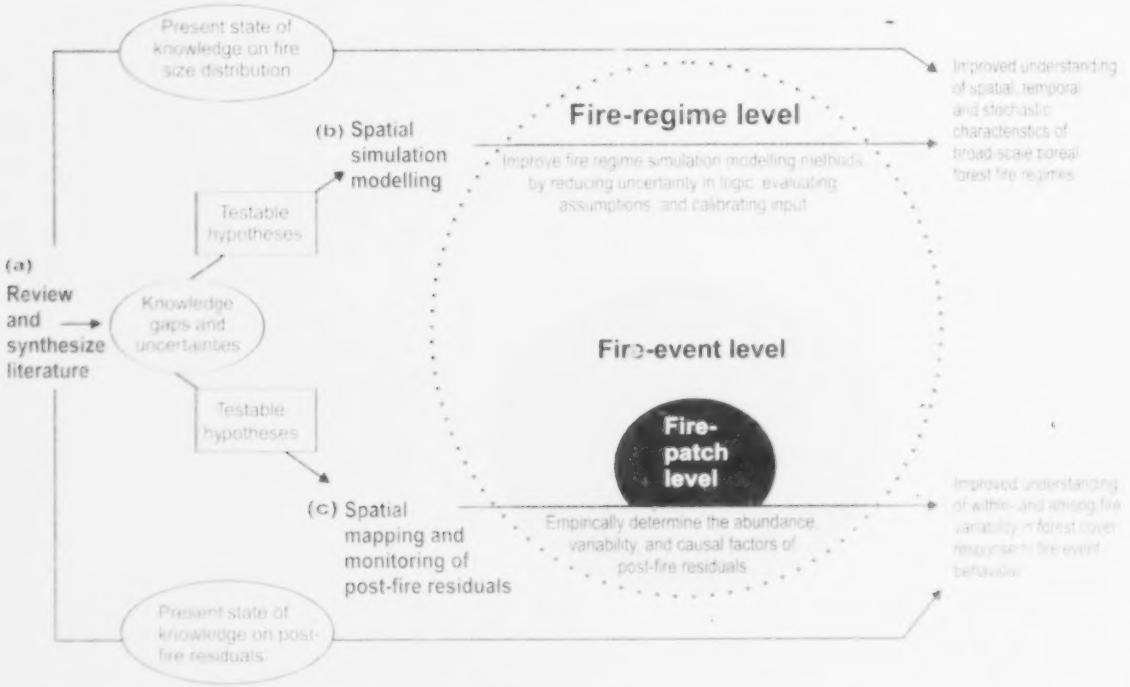
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Present state of knowledge on post-fire residuals

Figure 2. Focus and scale of planned research studies on boreal forest fire regimes and their linkages.

General scientific approach

The overall research approach incorporates core scientific principles of the PEL model (Gauch 2003), which dictates that conduct of sound science is based on an explicit combination of **p**re-suppositions (prior knowledge and common sense that lead to hypotheses), **e**vidence (explicit observations gathered through repeatable methods), and **l**ogic (unambiguous hypotheses constructed using non-circular reasoning either inductively or deductively and tested independently and without bias). This approach to conducting research not only ensures scientific rigour and reliability of methods and defensibility of the findings but also permits progressive advancement in knowledge in incremental steps. Adhering to explicit and unambiguous scientific methods is particularly important in ecological studies, because researchers' intimate familiarity with the subject matter (in this case forest fires and post-fire residuals) clouds objectivity and obscures the differences among pre-suppositions, evidence, and logic.

Our simulation modelling studies are based largely on deductive logic, and the empirical studies are based on inductive logic. In simulation modelling, we assemble the scientific and expert knowledge of forest fire processes as affected by weather, topography, and fuel types, as well as forest succession, and deductively estimate the probabilities of spatial occurrence and temporal frequency of forest fire events over large areas and long periods of time. This simulation modelling is an explicit and repeatable synthesis (logic) of process-based and empirical knowledge (presuppositions), and the results of such modelling are hypotheses. However, given the difficulty of methodically and reliably collecting empirical data on long term-large extent fire events, alternative approaches are being developed to increase the reliability (evidence) of simulation modelling results.

In empirical studies, we assemble the scientific knowledge of forest fire behaviour and response of forest vegetation to fire (presuppositions) to formulate explicit hypotheses (logic) on the occurrence and variability of the continuum (trees to patches) of forest fire residuals, as a spatially explicit function of causal factors. These hypotheses will be being tested based on empirical data (evidence) on forest fire residuals, collected by repeatable methods using inductive logic.

General tactical approach

A three-year plan (Figure 3) was developed outlining the resources needed to implement individual studies.

An advisory team comprising experts in forest research, fire science, forest policy, forest planning, and forest and wildlife ecology is in place to ensure that the studies are scientifically sound, relevant to MNR's policy needs, and linked to related ongoing studies (for details of study advisors, see Appendix II). In addition, advisors will assist in communicating scope, intent, and progress of research studies to others.

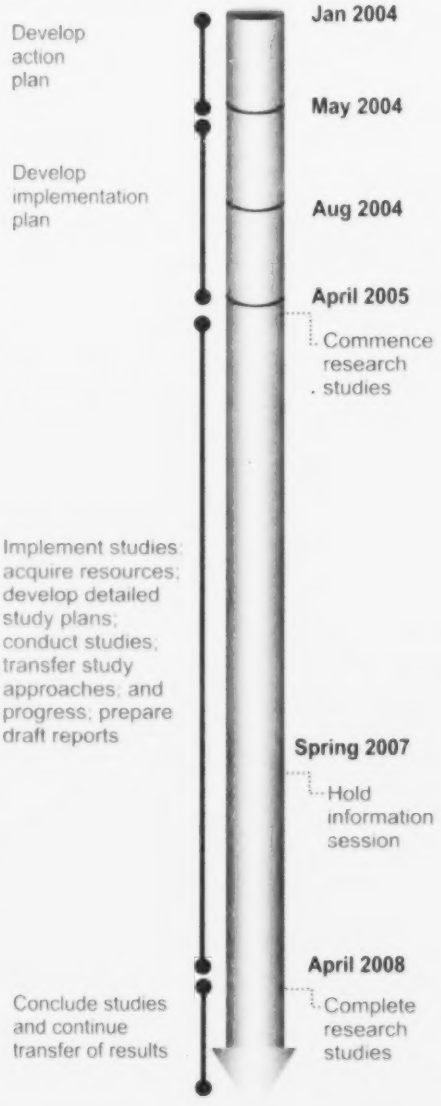
Develop action plan
Jan 2004
May 2004
Develop implementation plan
Aug 2004
April 2005
Commence research studies
Implement studies: acquire resources; develop detailed study plans; conduct studies; transfer study approaches; and progress; prepare draft reports
Spring 2007
Hold information session
April 2008
Conclude studies and continue transfer of results
Complete research studies

Figure 3. *Timeline for research studies on boreal forest fire regimes, including the planning stage.*

Research Studies

A description of each research study group is provided in the next section. The three broad groups of studies are literature review and syntheses, simulation modelling of fire regime, and spatially characterizing post-fire residuals. Each group is described with respect to the purpose (from perspectives of science and policy); research strategy (rationale for method); goals and specific objectives; methods (temporal phases, key steps, and techniques); and outcome (advances in scientific knowledge and information needed for policies and practices).

Study Group 1 - Reviews and syntheses of published literature of boreal fire regimes

This group includes two studies: (a) review and synthesis of published literature on fire size distribution and (b) review and synthesis of published literature on post-fire residuals at the tree and patch levels.

Purpose and goals:

By synthesizing the published but presently fragmented knowledge on fire size distribution and post-fire residuals at the tree and patch levels, researchers will be able to formulate hypotheses to advance science, and policymakers and resource managers will be able to assess the reliability of extant information.

In both studies, the goal is to understand the state of knowledge and to identify gaps and uncertainties in published knowledge on respective topics.

Strategy and methods:

The strategy and methods are the same for both studies. Present information in the literature on forest fire size distribution and post-fire residuals is fragmented and localized. As a result, the terminology, definitions, study methods, and findings are not generalized or synthesized. Our strategy is to formulate a hierarchical set of *a priori* questions that emphasize the variability and causal factors of fire size distribution and post-fire residuals, to guide information extraction and knowledge synthesis. As well, results, findings, and conclusions will be considered in light of the rigour of the study methods. As quality of study methods permit, all forms of scientific literature, ranging from technical documents to peer-reviewed publications, will be included in the review. The literature reviews will be based on inclusive keywords and common electronic bibliographical databases and involve sequential filtering by titles/keywords, abstract, and main text. Figure 4 presents a timeline for the study.

Study outcomes:

These literature reviews will advance scientific knowledge and reliability of information for policies and practices on emulating natural forest disturbances. For example, expected advances in scientific knowledge include:

- Synthesis of the knowledge and its uncertainties to formulate testable hypotheses on fire size distributions
- Synthesis of the knowledge and its uncertainties to formulate testable hypotheses on post-fire residuals at the tree and patch levels

Expected advances in reliability of information for policies and practices include:

- Explicitly identified state of knowledge, including uncertainties, and a broader quantitative basis for estimating fire size distributions
- Explicitly identified state of knowledge, including uncertainties and ambiguities about post-fire residuals at the tree and patch levels

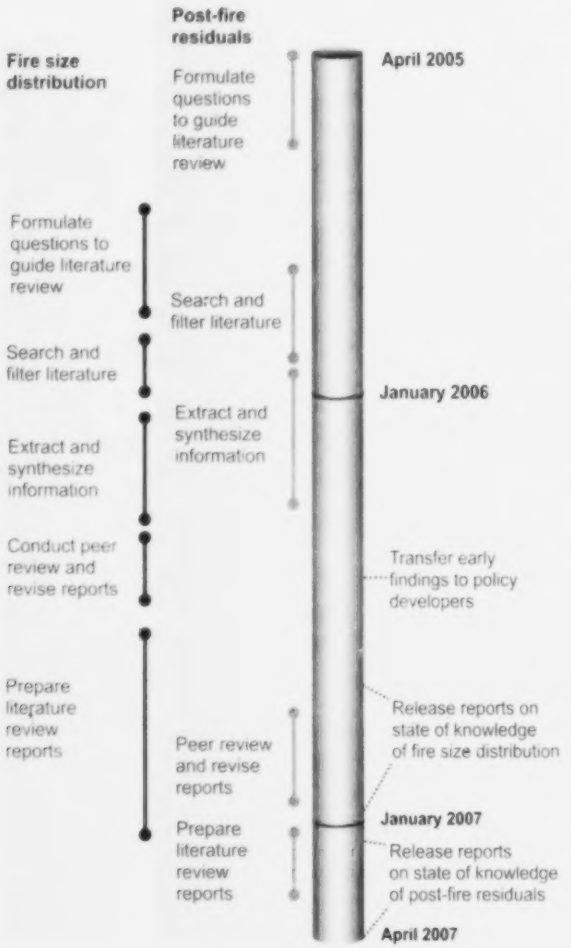
Fire size distribution
Post-fire residuals
April 2005
Formulate questions to guide literature review
Formulate questions to guide literature review
Search and filter literature
Search and filter literature
January 2006
Extract and synthesize information
Extract and synthesize information
Conduct peer review and revise reports
Transfer early findings to policy developers
Prepare literature review reports
Release reports on state of knowledge of fire size distribution
Peer review and revise reports
January 2007
Prepare literature review reports
Release reports on state of knowledge of post-fire residuals
April 2007

***Figure 4**. Timeline for literature reviews and synthesis study.*

Study Group 2 - Determining the characteristics of the broad-scale fire regime in boreal Ontario

This group of studies includes a series of parallel investigations to improve simulation modelling capabilities to reliably understand boreal forest fire regime in Ontario.

Purpose:

To understand the major characteristics of natural fires in boreal Ontario over large areas and long periods of time in terms of frequency and spatial tendency of fire events, fire size distribution, spatial and temporal variability and biases, and stochasticity of fire events.

By understanding the broad-scale fire regime and its variability, in natural conditions (i.e., minimal human intervention), forest policymakers will be able to provide better strategic guidance to emulate natural fire disturbance patterns by forest harvest.

Research strategy:

Present knowledge of the characteristics of boreal fire regimes stems primarily from assays of historical information of forest fire. While this approach describes past fire events and past fire regime, many uncertainties are associated with this knowledge. Methodologically, the narrow temporal and spatial windows of data collection for fire history studies limit the strength of the inference base and the scope of conclusions.

As a result, the uncertainty in the present scientific knowledge of boreal fire regimes is high, particularly with respect to spatial patterns and variability. The literature contains limited reliable information on frequency and spatial tendency of fire events, fire size distribution, spatial and temporal variability and biases, and stochasticity of fire events. However, scientific knowledge of individual processes that affect forest fire behaviour is relatively more reliable.

Therefore, this study will embrace a simulation modelling approach, where mechanistic knowledge of basic processes in fire ecology and empirical data on weather, land cover, and other geo-environmental variables are synthetically combined and applied under explicit sets of assumptions. This approach is practical given the large extent (hundreds of thousands of square kilometres) and the long time periods (several centuries) needed to understand patterns in forest fire regimes. It is also effective for exploring many *what-if* assumptions about factors influencing forest fire and succession and, therefore, the potential forest fire regime of given landscapes. The potential fire regime will be characterized by the spatial, temporal, and random variability of forest fire-succession dynamics and expressed as a realm of probabilities (what could occur) rather than as deterministic forecasts (what would occur) (Figure 5).

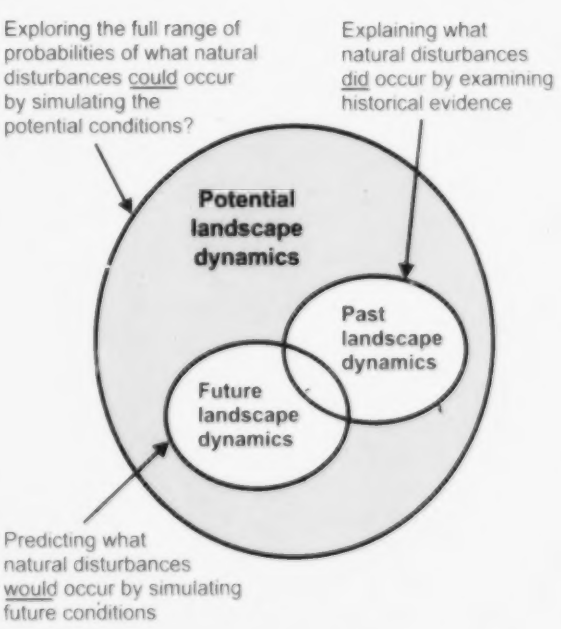
Exploring the full range of probabilities of what natural disturbances could occur by simulating the potential conditions?
Explaining what natural disturbances did occur by examining historical evidence
Potential landscape dynamics
Past landscape dynamics
Future landscape dynamics
Predicting what natural disturbances would occur by simulating future conditions

Figure 5. *Different approaches for exploring landscape dynamics and their outcome.*

Goals and objectives:

The primary goal is to characterize the potential forest fire regime in boreal Ontario and to identify the spatial, temporal, and random variability of occurrences and sizes of fire events.

The following study objectives will contribute to the above goal:

1. Develop a scientifically sound simulation model of forest landscape dynamics that will contain the best scientific knowledge on basic component processes (forest fire behaviour and forest succession) of forest fire regimes
2. Identify uncertainties in the present scientific knowledge of component processes: forest fire ignition, fire growth, fire extinguishment, post-fire species establishment, and forest succession
3. Evaluate the sensitivity of model performance and output to major knowledge uncertainties and model assumptions
4. Simulate the frequency and spatial tendency of fire events, fire size distribution, and spatial and temporal variability and biases associated with the boreal forest fire regime in Ontario

Methods:

The overall methodology of this study has four phases:

Phase 1: Review the fire science literature and establish the state of knowledge on fire size distributions and their variability in boreal forests.

Phase 2: Identify the improvements needed in the model component logic and input requirements of BFOLDS v.1.0 (Boreal Forest Landscape Dynamics Simulator), a raster-based simulation model of the potential fire regime at spatial and temporal scales appropriate for study goals (Perera et al. 2003). Figure 6 illustrates the complexity and probability of fire disturbance-based landscape dynamics and the logic in model components. Identify major uncertainties in BFOLDS fire simulation algorithms by comparing model performance with other fire process simulation models based on the Canadian Forest Fire Behaviour Prediction system. The fire algorithms to be evaluated are fire ignition patterns, fire spread functions (especially in relation to fuel patterns and wind), and fire extinguishment. Identify major uncertainties in expert knowledge used in BFOLDS forest succession algorithms by evaluating regional expert succession rules for their reliability and variability in modelled scenarios. Compare and consolidate presently disparate succession knowledge, from expert opinion and the published literature, to formulate hypotheses that can be tested with empirical spatial data to identify reliability and remaining uncertainty of succession rules used to generate fire regime simulations.

Phase 3: Improve BFOLDS' component logic and assumptions by enhancing fire simulation algorithms, increasing reliability of forest succession knowledge, and augmenting use of meteorological information. Develop ability to explore effect of climate change scenarios on potential fire regimes by enhancing BFOLDS' use of fire weather information. Conduct model sensitivity analyses to input data types, resolutions, assumptions, and ecological region boundaries. Encode improved model algorithms to improve model performance and efficiency, yet maintain transparency of simulation logic. Discover variability of simulated fire regime and explanatory factors of temporal and spatial variability (Figure 7).

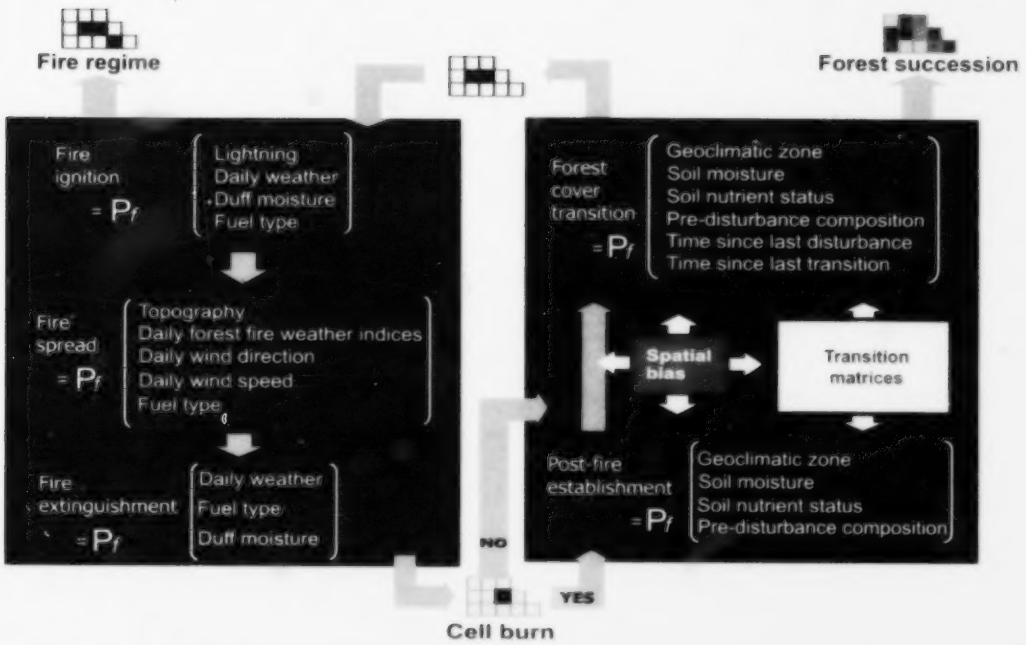

Figure 6. *Major components of the fire simulation model BFOLDS, illustrating multiple probabilities associated with simulating fire regime.*

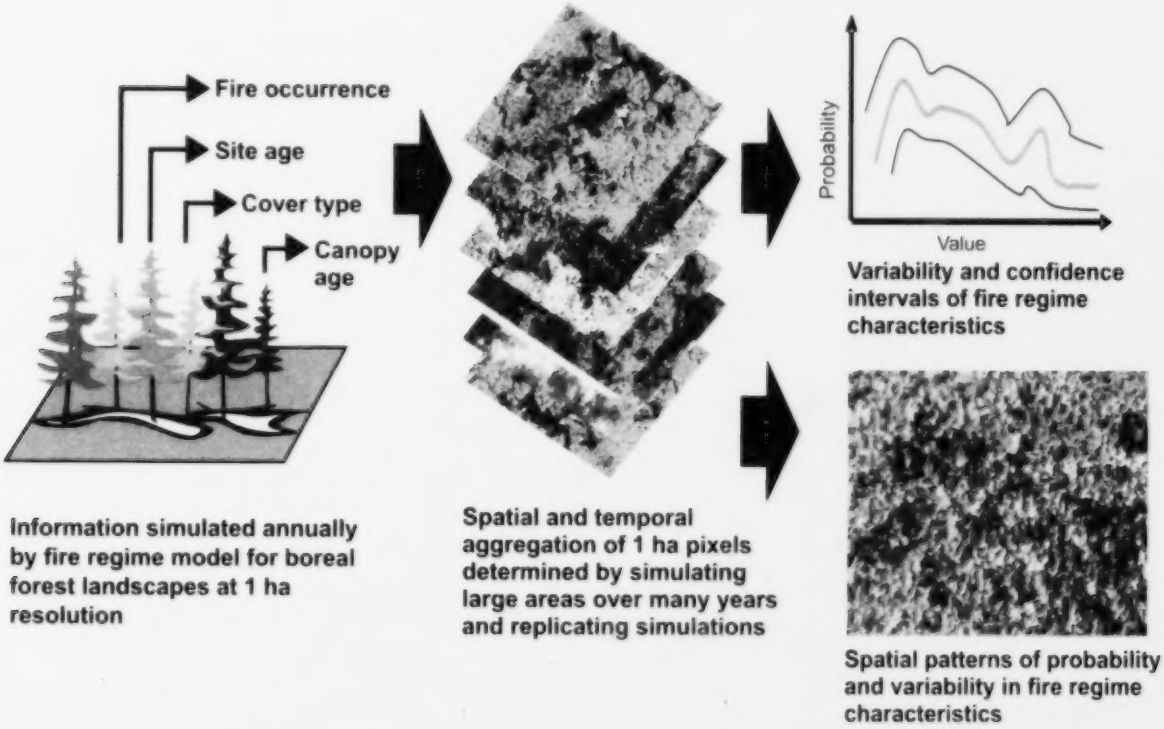
Fire occurrence
Site age
Cover type
Canopy age
Probability
Value
Variability and confidence intervals of fire regime characteristics
Information simulated annually by fire regime model for boreal forest landscapes at 1 ha resolution
Spatial and temporal aggregation of 1 ha pixels determined by simulating large areas over many years and replicating simulations
Spatial patterns of probability and variability in fire regime characteristics

Figure 7. *Using simulated forest fire attributes to characterize the potential forest fire regime in boreal Ontario and to identify the spatial, temporal, and random variability of occurrences and sizes of fire events.*

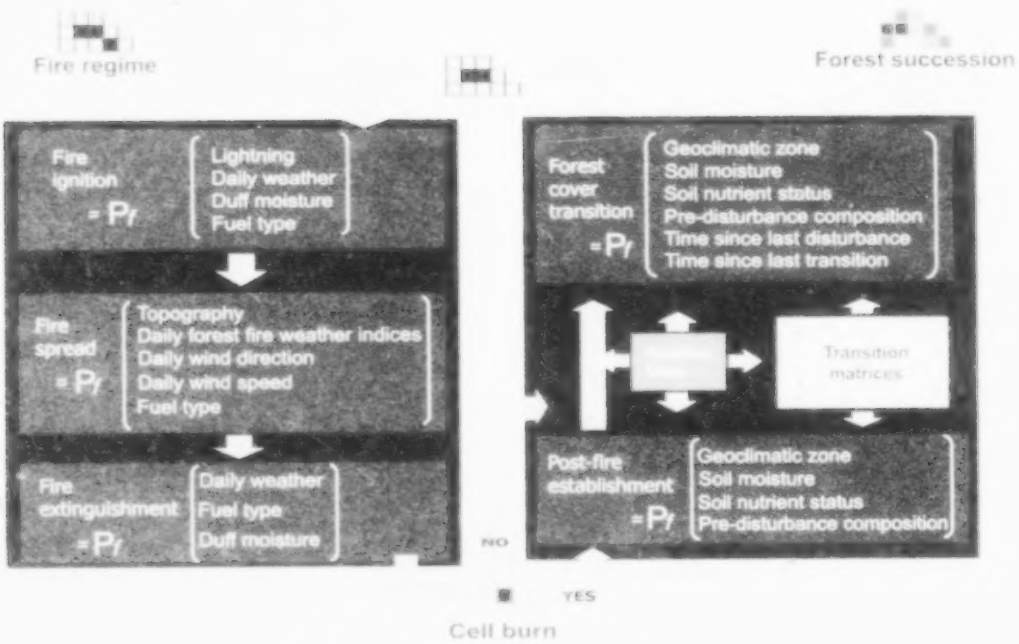

Figure 6. Major components of the fire simulation model BFOLDS, illustrating multiple probabilities associated with simulating fire regime.

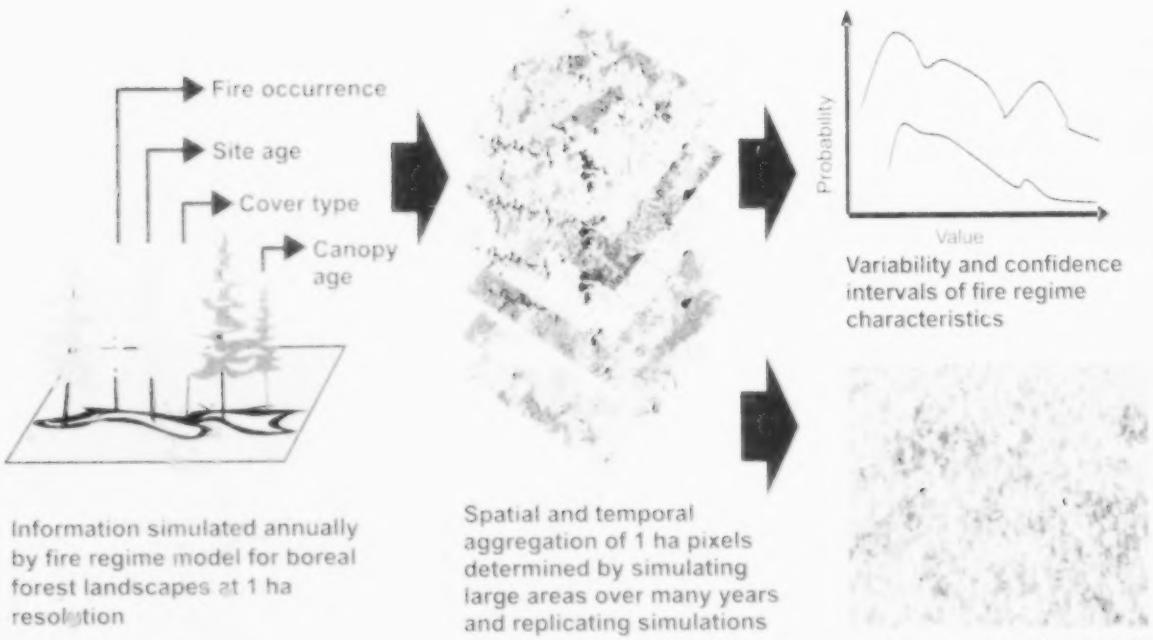
Fire occurrence
Site age
Cover type
Canopy age
Probability
Value
Variability and confidence intervals of fire regime characteristics
Information simulated annually by fire regime model for boreal forest landscapes at 1 ha resolution
Spatial and temporal aggregation of 1 ha pixels determined by simulating large areas over many years and replicating simulations
Spatial patterns of probability and variability in fire regime characteristics

Figure 7. Using simulation modelling techniques to characterize the potential forest fire regime in boreal Ontario and to identify the spatial, temporal, and random variability of occurrences and sizes of fire events.

Phase 4: Conduct simulations with the improved model (BFOLDS v.1.5) and under an explicit set of assumptions, input data, and appropriate ecological regions (Figure 8), characterize the potential fire regime with respect to spatial, temporal, and random variability of occurrences and sizes of fire events.

Figure 9 presents a timeline for the study.

Study outcomes:

This study will advance scientific knowledge and reliability of information for policies and practices on broad-scale fire regimes in boreal Ontario.

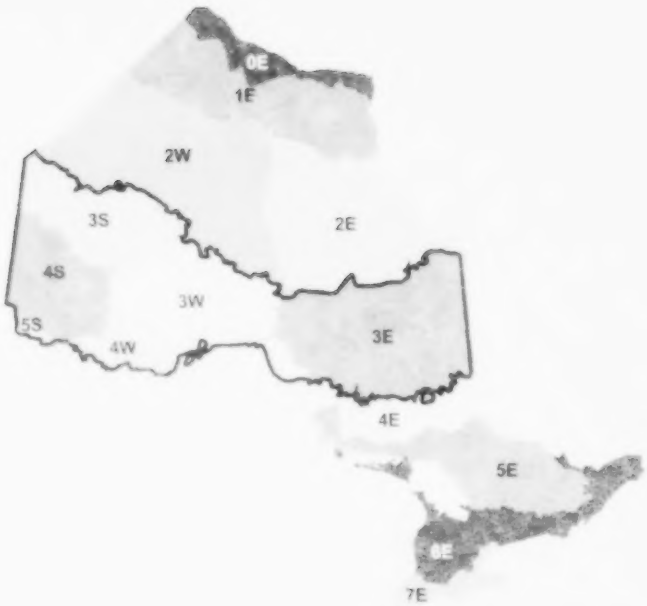

Figure 8. Ecoregions in Ontario selected (highlighted) for simulation modelling to explore their appropriateness for capturing variability in the fire regime.

Expected advances in scientific knowledge include:

- Improvements in knowledge of fire process modelling and boreal forest succession
- Improvements in understanding boreal forest fire regimes through synthesis of the knowledge of fire science, forest succession, spatial statistics, and modelling techniques
- Hypotheses on patterns and variability of the forest fire regime in boreal Ontario under conditions of minimal human intervention

Expected advances in reliability of information for policies and practices include:

- Documented and defensible methods of arriving at findings on the potential fire regime in Ontario's boreal forests
- Explicitly identified uncertainties about knowledge of forest fire, forest succession, and spatial databases
- Quantitative estimates of spatial, temporal, and random variability of occurrences and sizes of fire events in a potential fire regime.

As well, this study will produce a multi-use simulation model that can be used to explore the potential fire regime of boreal forests in a spatially explicit, stochastic, and incrementally improvable manner.

Phase 4: Conduct simulations with the improved model (BFOLDS v.1.5) and under an explicit set of assumptions, input data, and appropriate ecological regions (Figure 8), characterize the potential fire regime with respect to spatial, temporal, and random variability of occurrences and sizes of fire events.

Figure 9 presents a timeline for the study.

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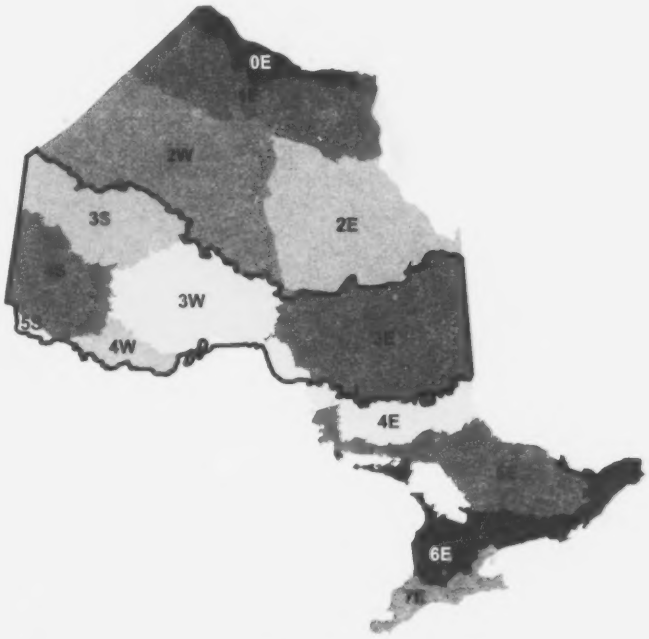

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- Quantitative estimates of spatial, temporal, and random variability of occurrences and sizes of fire events in a potential fire regime.

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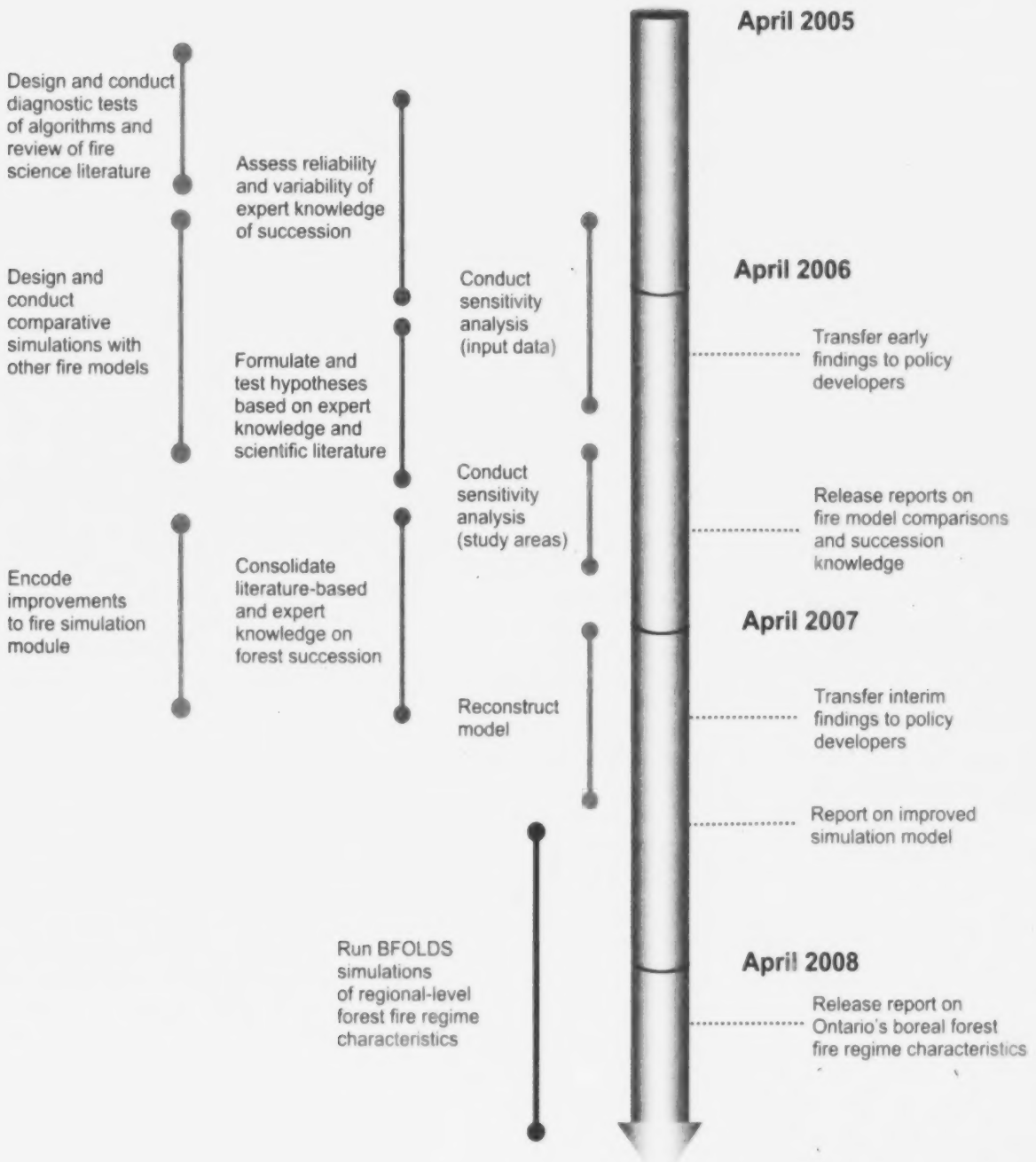
April 2005
Design and conduct diagnostic tests of algorithms and review of fire science literature
Assess reliability and variability of expert knowledge of succession
Design and conduct comparative simulations with other fire models
Conduct sensitivity analysis (input data)
April 2006
Transfer early findings to policy developers
Formulate and test hypotheses based on expert knowledge and scientific literature
Conduct sensitivity analysis (study areas)
Release reports on fire model comparisons and succession knowledge
Encode improvements to fire simulation module
Consolidate literature-based and expert knowledge on forest succession
April 2007
Reconstruct model
Transfer interim findings to policy developers
Report on improved simulation model
Run BFOLDS simulations of regional-level forest fire regime characteristics
April 2008
Release report on Ontario's boreal forest fire regime characteristics

Figure 9. *Timeline for spatial simulation modelling of the broad-scale fire regime in boreal Ontario.*

Study Group 3 - Spatial mapping and monitoring of post-fire residuals

This group includes two main studies, which will investigate post-fire residuals at two spatial scales: (a) patch level and (b) tree level.

Study 3 (a): Patch-level residuals

This study involves spatially characterizing aggregates of live tree residuals in unsuppressed boreal forest fires.

Purpose:

To understand the extent of post-fire residual live trees, their spatial patterns of aggregation, within- and among-fire variability, and explanatory factors for their spatial variability and extent (such as fire behaviour, pre-burn composition, and their interactions). By understanding the above spatial characteristics and variability of post-fire residual aggregates in natural conditions, forest policymakers can provide better strategic guidance to emulate natural fire disturbance patterns by forest harvest, and forest managers will be able to make better tactical decisions about how much and where to leave post-harvest residual aggregates to emulate fire disturbances.

Research strategy:

Uncertainty in scientific knowledge of post-fire residual patches in the boreal forest is high. The definitions of *residuals* are inconsistent and ambiguous; characteristics of study fires are not clear; the number of observed fires is low; spatial variability of residual aggregates is not explained; and causal factors for residual occurrence and variability aren't identified. Moreover, there are no hypotheses proposed in literature for us to directly test in this study.

Given the inadequacies in the state of knowledge, this study is restricted to baseline research that will ask fundamental questions and answer them in a way that we can formulate testable hypotheses for future research. Some sample questions we will pose are: How is a residual patch defined based on the composition and aggregation of live trees? Is residual tree occurrence and their aggregation a function of pre-burn composition, fire behaviour, and/or their interaction? How variable are the residual aggregates, and what factors explain that variation?

A simulation modelling approach cannot be used in this study because fire simulation models available to date cannot reliably explain tree-level fire behaviour at the scale of a fire event, and the interaction between fire and forest vegetation is based on process-based knowledge. Even if such fine-scale models were available, the geo-environmental databases needed to adequately and reliably capture pre-burn scenarios and the fire behaviour process as a function of micro-weather and physiographic patterns are not available.

Therefore, the study approach will be empirical: Data will be collected from actual fires, analyzed for spatial patterns, and correlated with observed geo-environmental variables.

Goals and objectives:

The primary goal is to spatially characterize post-fire live tree residual aggregates in natural boreal forest fires, understand the variability, and identify major causal factors of occurrence.

The following study objectives will contribute to this goal:

1. Estimate the expected extent and variability of live tree residuals within forest fires
2. Determine the degrees of aggregation of live tree residuals to form patches

3. Identify the spatial geometry of residual tree aggregates within fires
4. Identify geo-environmental causal factors associated with spatial biasing of residuals

Methods

As mentioned above, the study strategy is to conduct an empirical survey, statistically analyze the extent and variability of residual aggregates, correlate them to spatial geometry of burns and geo-environmental variables, and formulate hypotheses for future studies. The overall methodology consists of three phases:

Phase 1: Locate an adequate sample of unsuppressed boreal forest fires in Ontario of various sizes that occurred within the past five years (Table 2), and map those using a very high-resolution remote sensing method. Classify images using a raster-based supervised classification to identify three categories of burns: unburnt, partially burnt, and completely burnt. Identify and classify each raster separately without delineation of *patches* of residuals. As well, identify the composition of unburned rasters (Figure 10). This phase will produce the extent of post-fire residual aggregates and their within- and among-fire variability.

Table 2. *Attributes of unsuppressed boreal forest fires studied for post-fire residual tree aggregates.*

Fire year	MNR fire ID #	MNR estimate of fire area (ha)
2003	SLK55	16,050
2003	SLK51	9680
2003	SLK80	760
2003	NIP92	230
2002	RED5	15,000
2002	SLK31	6050
2002	RED23	4480
2002	RED27	4470
2002	RED21	3940
2002	SLK1	3860
2002	NIP32	3190
2002	RED34	2750
2002	RED40	550
2002	NIP38	390
2002	RED56	310
2002	NIP47	130
2002	SLK3	90
2002	NIP48	90
2002	SLK2	50
2002	SLK36	50
2001	NIP73	2250
2001	NIP72	380
2001	NIP52	300
2001	SLK5	80
1999	NIP43	1510
1999	SLK82	500
1999	NIP52	230
1998	SLK104	2110
1998	SLK105	1350
1998	NIP144	640
1998	NIP124	240
1998	SLK75	210
1998	SLK106	70
1998	RED39	60

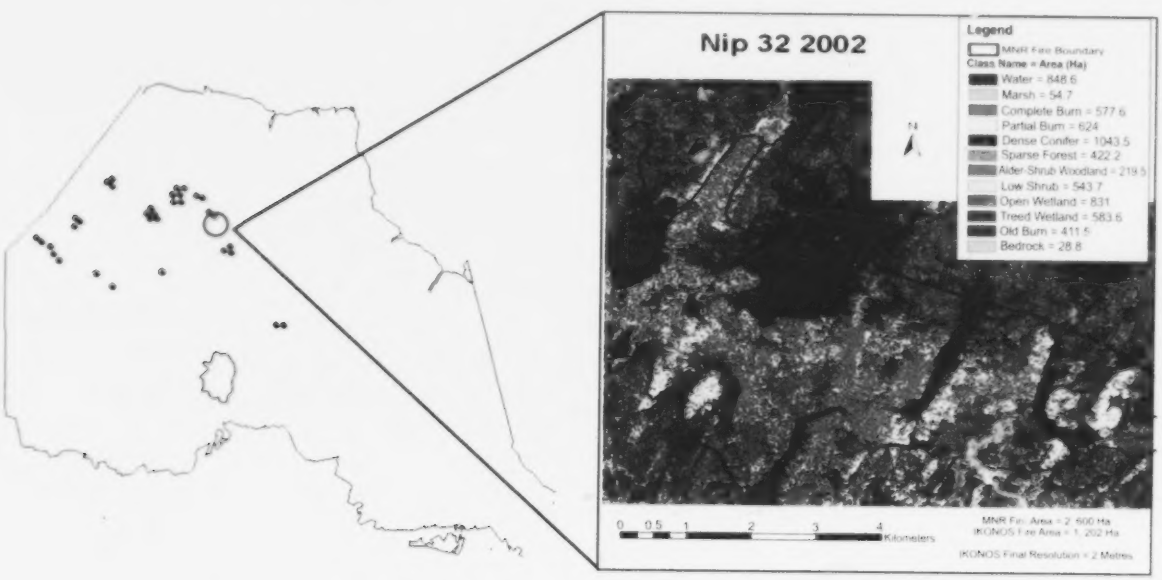

Figure 10. *Locations of unsuppressed fires studied by high-resolution satellite imagery for post-fire residual tree aggregates.*

Phase 2: Conduct a series of spatial analyses to discern the nature of aggregation of unburnt and partially burnt rasters in forming patches. This phase will produce the degree of patch formation in live tree residuals, size-class distribution of patches, geometrical spatial biases of patches within fires, and variability in patches among fires.

Phase 3: Conduct a series of statistical analyses of the residual aggregates to identify correlations and spatial biases of live tree residual patches to pre-burn vegetation, fire weather, and geo-environmental variables such as wetlands and water bodies. This phase will produce a series of first-order hypotheses on mechanistic reasons for formation and variability of live tree residual aggregates within boreal forest fires.

A timeline for the study is provided in Figure 11.

Study outcomes:

This study will advance scientific knowledge and the reliability of information for policies and practices related to residual tree aggregates. Expected advances in scientific knowledge include:

- Baseline information on occurrence, patterns, and variability of residual tree aggregates in Ontario's boreal forest
- Hypotheses on causal factors of extent and patterns in residual tree aggregates in boreal forest fires

Expected advances in reliability of information for policies and practices include:

- Documented and defensible methods of arriving at findings
- Explicitly identified uncertainties about knowledge of residual tree aggregates
- Quantitative estimates of residual tree aggregate occurrences and their within- and among-fire variability

As well, multi-use spatial residual tree aggregate datasets on unsuppressed fires will be produced.

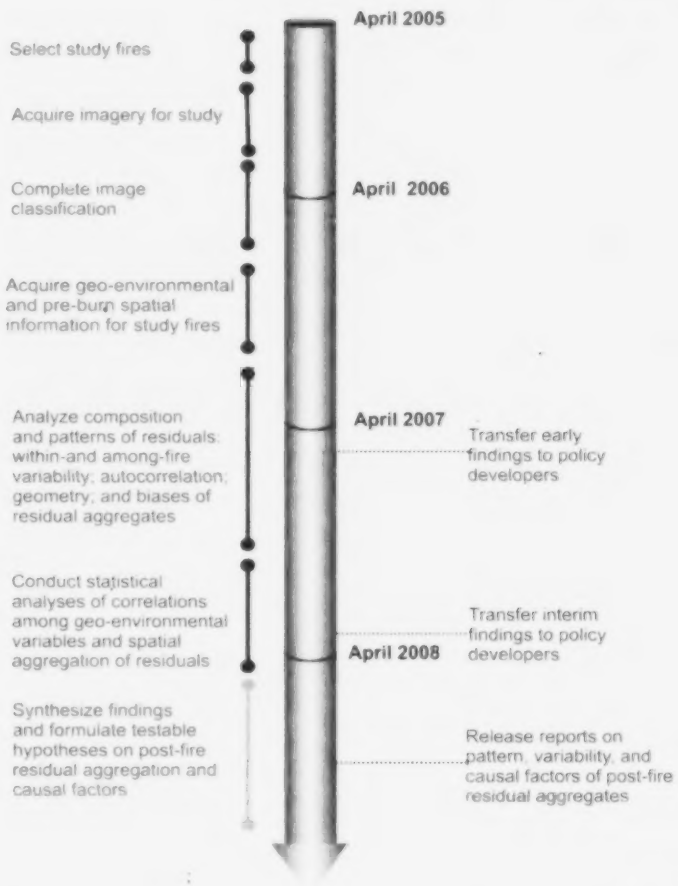
April 2005
Select study fires
Acquire imagery for study
Complete image classification
April 2006
Acquire geo-environmental and pre-burn spatial information for study fires
Analyze composition and patterns of residuals: within-and among-fire variability; autocorrelation; geometry; and biases of residual aggregates
April 2007
Transfer early findings to policy developers
Conduct statistical analyses of correlations among geo-environmental variables and spatial aggregation of residuals
Transfer interim findings to policy developers
April 2008
Synthesize findings and formulate testable hypotheses on post-fire residual aggregation and causal factors
Release reports on pattern, variability, and causal factors of post-fire residual aggregates

Figure 11. *Timeline for the spatial characterization study of live tree residual aggregates in unsuppressed boreal forest fires.*

Study 3 (b): Tree-level residuals

This study involves characterizing the abundance and spatial-temporal variability in residual stand structure within unsuppressed boreal forest fire events.

Purpose:

To understand the extent of post-fire residual structure (live trees, snags, and downed wood), its within- and among-fire variability, and explanatory factors for spatial variability and extent (such as fire behaviour, site conditions, and pre-burn composition and their interactions), as well as short-term dynamics. By understanding the above characteristics and spatial-temporal variability of post-fire residual structure in natural conditions, forest policymakers can provide better strategic guidance to emulate natural fire disturbance patterns by forest harvest, and forest managers can make better tactical decisions about how much and where to leave post-harvest residual structure to emulate fire disturbances.

Research strategy:

Uncertainty in the scientific knowledge of post-fire residual structure in boreal forests is moderate. While many researchers have studied residual structure, it is not consistently defined and terms are often a used ambiguously; characteristics of study fires are often not well documented; number of observed fires sampled is often low; spatial variability of residual structure is not explained; and causal factors for residual occurrence and variability are not identified. Previous research on post-fire residual structure does, however, provide the basis for developing a conceptual model and series of hypotheses that can be tested in this study.

Similar to the spatial aggregation study described previously, a simulation modelling approach cannot be used in this study because fire simulation models available to date cannot reliably explain tree-level fire behaviour at the scale of a fire event. Therefore, an empirical approach will be applied: Data will be collected from actual fires, analyzed for spatial pattern, and correlated to other observed geo-environmental variables.

Goals and objectives:

The broad goal of this study is to characterize post-fire residual structure in boreal forests, understand its variability, identify major causal factors of occurrence, and document its short-term dynamics.

The following study objectives will contribute to this goal:

1. Estimate the expected extent and variability of residual structure within fire events
2. Identify geo-environmental causal factors associated with spatial biasing of residual structure
3. Document immediate post-fire dynamics of residual structure

Methods

As mentioned above, the strategy is to conduct an empirical survey, statistically analyze the extent and variability of residual structure, and correlate them to pre-burn stand characteristics, geo-environmental variables, and fire behaviour. The overall methodology has of four phases:

Phase 1: Review the literature to develop a conceptual model and research hypotheses, with a focus on current unknowns and causal factors of occurrence and variability.

Phase 2: Locate an adequate sample of unsuppressed areas of current-year boreal forest fires in Ontario, and sample those using high-resolution photography, sampling across various distances from fire perimeter, water bodies, etc., and avoiding live tree residual aggregate patches (Figure 12). Interpret images (Figure 13) for type, amount, and spatial distribution of post-fire structure; conduct field sampling to assess error (Figure 14) of interpreted data; and analyze both datasets. This phase will provide the extent of post-fire residual structure and its within- and among-fire variability.

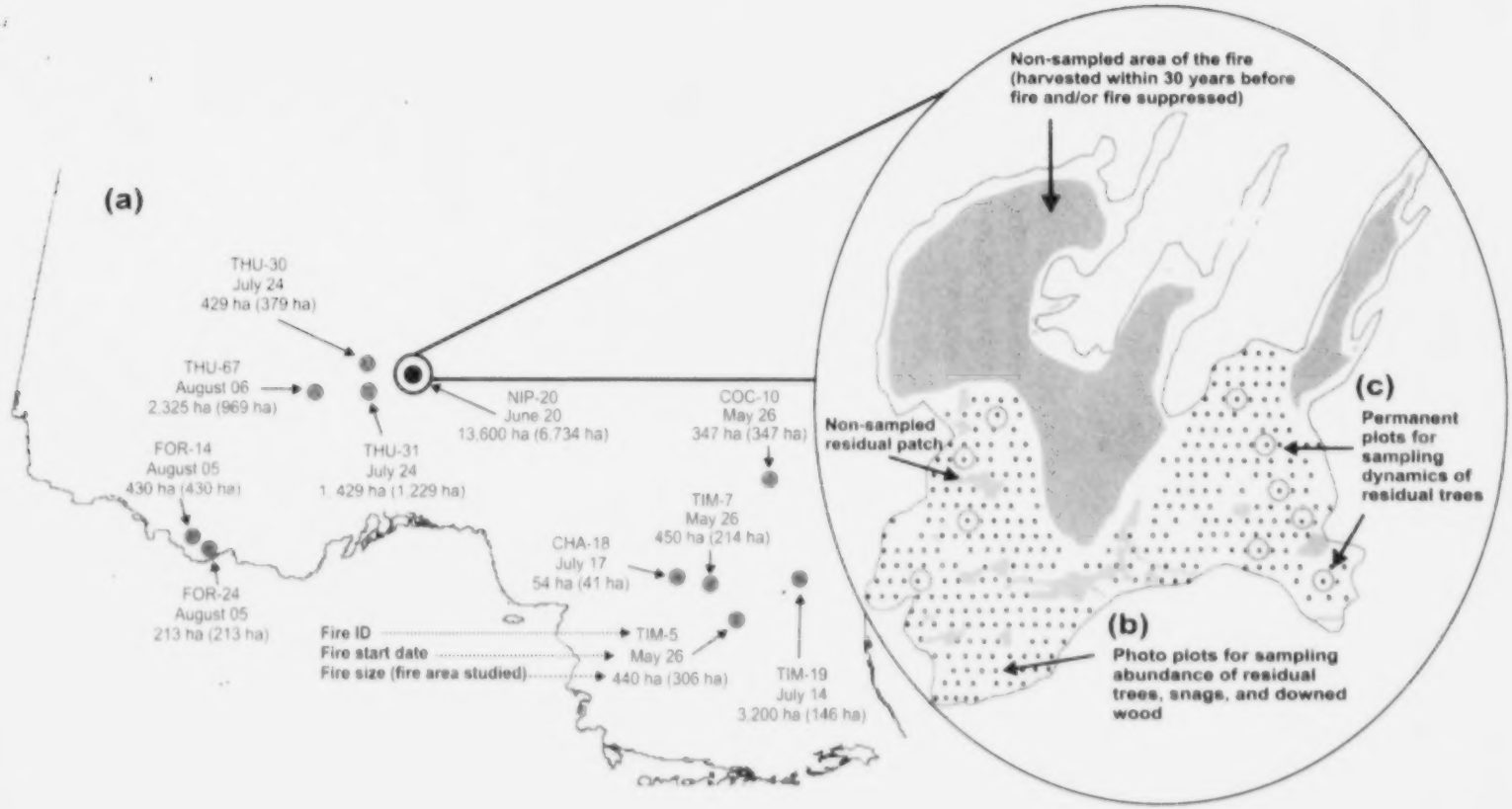

***Figure 12**. Locations of 2005 forest fires studied by high-resolution photos (HRP) (a), sample plots in unsuppressed parts (b) and permanent sample plots (c).*

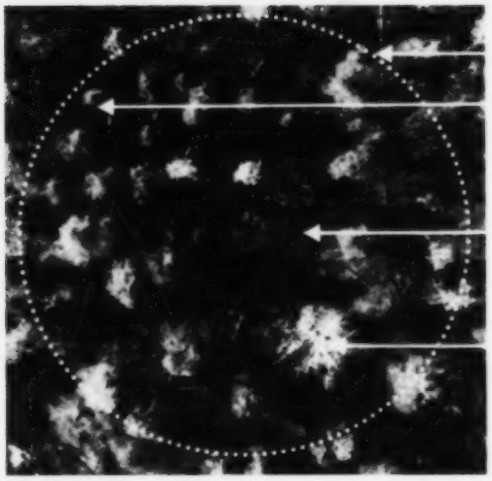

Figure 13. *High-resolution photo showing post-fire residual structure in a sample plot.*

Figure 14. *Field sample plot used to assess error and monitor residual structure dynamics in post-fire stand structure study.*

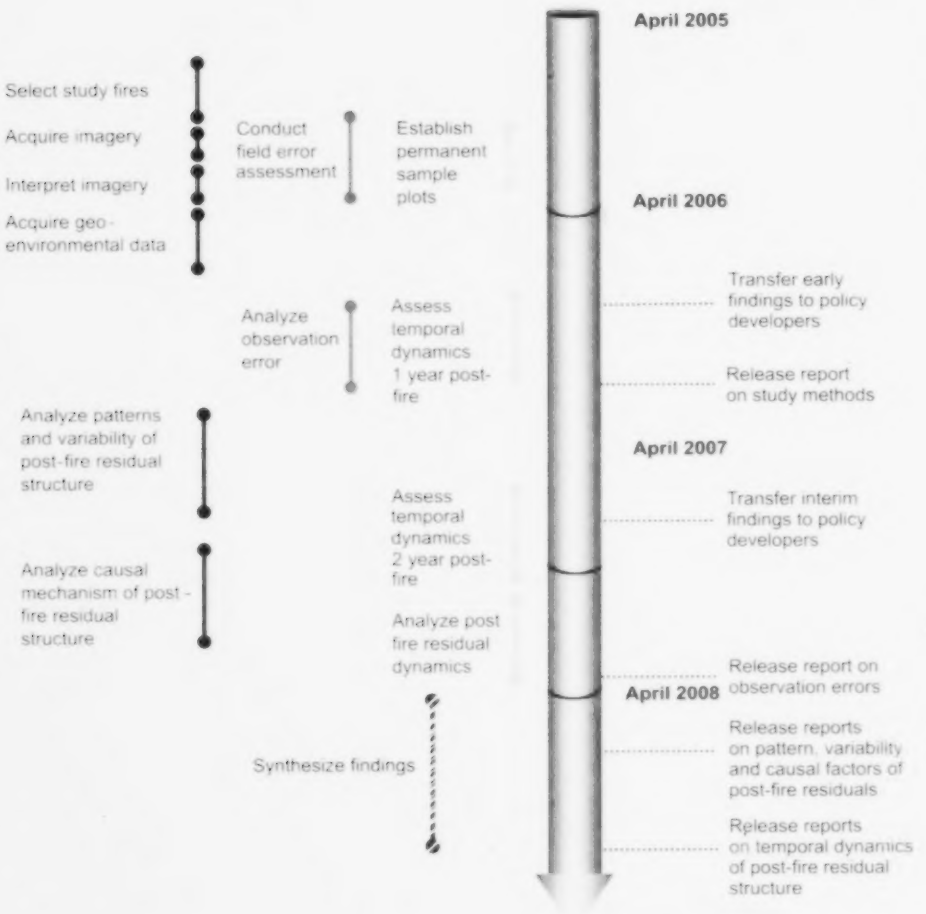
Select study fires
Acquire imagery
Interpret imagery
Acquire geo-environmental data
Conduct field error assessment
Establish permanent sample plots
Analyze observation error
Assess temporal dynamics 1 year post-fire
Analyze patterns and variability of post-fire residual structure
Assess temporal dynamics 2 year post-fire
Analyze causal mechanism of post-fire residual structure
Analyze post fire residual dynamics
Synthesize findings
April 2005
April 2006
Transfer early findings to policy developers
Release report on study methods
April 2007
Transfer interim findings to policy developers
Release report on observation errors
April 2008
Release reports on pattern, variability and causal factors of post-fire residuals
Release reports on temporal dynamics of post-fire residual structure

Figure 15.
Timeline for the study on characterizing abundance and spatial-temporal variability in residual stand structure in unsuppressed boreal forest fires.

Research Products and Transfer of Knowledge

Publications and databases

The main products from these studies will be publications and multi-use databases. All publications will be peer-reviewed by both MNR and external reviewers to assure scientific quality and applicability of the information. These publications will target a range of audiences, including policymakers, practitioners, and researchers. Table 3 contains a list of proposed publications for each research study. As well, databases that are of value to other researchers for uses beyond fire disturbance studies will be compiled or generated. They will include bibliographic databases, empirical data observations, simulated scenarios, and ancillary spatial databases (Table 3).

Table 3. *A sample list of products that will be generated by the research studies on fire regimes.*

Study focus	MNR research reports	Research articles	Sample multi-use databases
Literature review	• State of knowledge on fire size distribution in boreal forests • State of knowledge on post-fire residual structure in boreal forests	• Knowledge of fire size distribution and its use in boreal forest management in North America • Knowledge of and uncertainty in boreal post-fire residuals • ...	• Bibliographic databases of literature
Broad-scale fire regime	• Spatial, temporal, and random variability in fire size distribution and spatial proximity of fires in boreal Ontario • Assessing the uncertainty, variability, and reliability in expert knowledge of boreal forest succession in Ontario • Regionality in boreal forest fire regime characteristics in Ontario • ...	• A theoretical and empirical comparison of three Canadian fire spread models • How well do fire spread models predict real forest fires? • Capturing and consolidating knowledge on boreal forest succession • Testing landscape-scale boreal forest succession rules as hypotheses • Spatial biases in simulated boreal forest fires • Simulation of forest landscape dynamics at ecoregional scale • ...	• Bibliographic databases of literature • Spatial surfaces of simulated fire regime characteristics for boreal ecoregions • Tested and validated spatially explicit rule sets for boreal forest succession • Spatial databases of forest fuel, soil, fire-weather, and terrain
Live tree residual aggregates	• An assessment of the extent and variability of insular and peninsular post-fire residual patches in unsuppressed boreal forest fires	• Spatial geometry and variability in residual tree aggregates in unsuppressed boreal forest fires • What factors influence the formation of post-fire tree residual aggregates? • How well can fire growth models simulate residual aggregates? • ...	• High-resolution satellite imagery of unsuppressed boreal forest fires • Spatial databases of forest fuel and fire-weather for study forest fires
Residual stand structure	• An assessment of the extent and variability of post-fire residual stand structure in unsuppressed boreal forest fires • Early temporal dynamics of live tree and snag residuals in boreal forest fires	• Errors associated with estimating residual stand structure by high-resolution photographs • Within- and among-fire variability in post-fire residual stand structure in boreal forests • What factors influence the occurrence and temporal dynamics of post-fire tree residual structure? • ...	• High-resolution photographic imagery of residual stand structure in unsuppressed boreal forest fires • Permanent sample plots for monitoring long-term dynamics in residual stand structure • Spatial databases of forest fuel and fire-weather for studying forest fires

Transfer of knowledge

Products described in the previous section will be conveyed to users through a knowledge transfer plan developed concurrently with research study designs. The approach here is to actively engage users from the outset and throughout the study period to ensure that their needs are considered in developing research studies and to ensure that they are aware of study findings in advance, allowing them to incorporate that knowledge into policy and practice quickly and efficiently. In addition, research studies benefit from user insight during study design and implementation.

The primary user audiences comprise policymakers (those who prepare policy documents) and forest resource managers (field foresters and biologists in government and industry). A secondary audience consists of the decisionmakers (management hierarchy in government). Transfer goals are geared to different user audiences and require different approaches and activities (Table 4). These activities are continuous; some are concurrent, others sequential. They are organized in three major phases (Figure 16).

During the study development phase, the transfer goal is to ensure the rationale, objectives, and methods of the studies are acceptable to both primary and secondary user audiences and relevant to their needs. This goal will be accomplished by engaging user audiences to seek their views on research questions and study design through structured study advisory teams, as well a series of presentations and informal meetings. These activities will enable users to be aware of limitations and uncertainty of present knowledge and to envision uses of this information in developing future policies and practices.

As research studies progress, user audiences will be continuously engaged through advisory team meetings, presentations, field visits, and informal meetings. Interim results and progress in studies will also be communicated via annual reports. At a mid-point in the study period, a series of general information sessions will be held to communicate goals, methods, interim findings, and knowledge advances to a broader audience. This information may help users find scientific solutions to their policy and management needs before scientific publications are produced.

The goal of the final phase is to transfer study findings to user audiences through various means (beyond publishing peer-reviewed documents) to ensure those are readily available to policy developers and forest resource managers. This transfer phase will continue beyond the formal study period.

Table 4. *Main audiences, transfer goals, and associated activities for research studies on boreal fire regimes.*

Audience	Transfer goals	Transfer activities
Policy makers	• Provide reliable and defensible information for policy development	Periodic communication, Informal meetings, Presentations, Field visits, Information session, Annual reports, Scientific publications
Policy makers	• Improve understanding of probabilities and variability of fire disturbance	
Forest resource managers	• Improve understanding of mechanisms and causal factors of fire disturbances and residual structure	
Forest resource managers	• Provide reliable and useful information for forest management planning	
Decision-makers	• Improve understanding of the knowns and unknowns of knowledge in polices and practices	
Decision-makers	• Improve understanding of the ongoing research to foster linkages and collaborations	

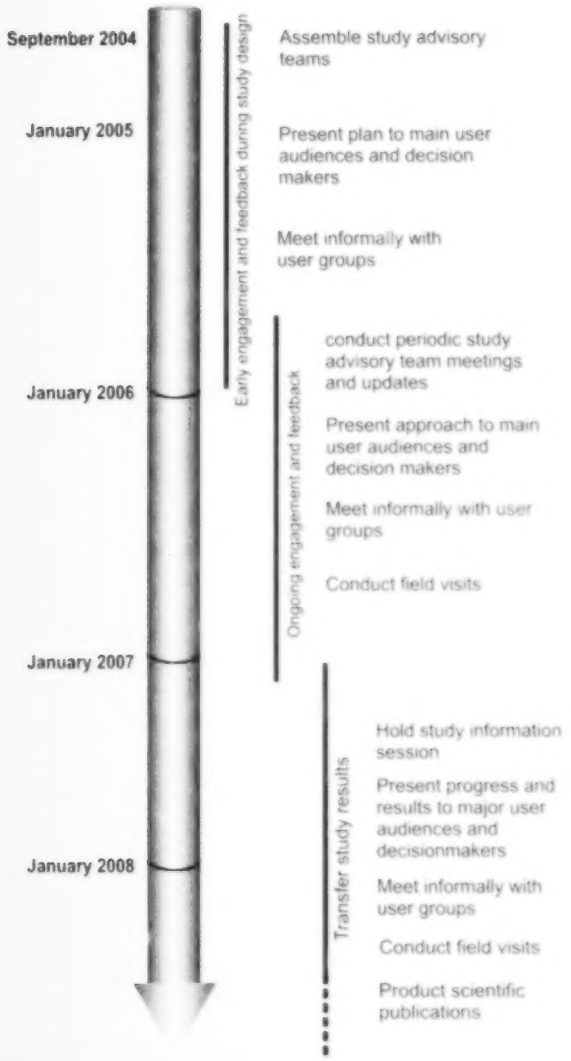
September 2004
January 2005
January 2006
January 2007
January 2008
Early engagement and feedback during study design
Assemble study advisory teams
Present plan to main user audiences and decision makers
Meet informally with user groups
Ongoing engagement and feedback
conduct periodic study advisory team meetings and updates
Present approach to main user audiences and decision makers
Meet informally with user groups
Conduct field visits
Transfer study results
Hold study information session
Present progress and results to major user audiences and decisionmakers
Meet informally with user groups
Conduct field visits
Product scientific publications

Figure 16. *Timeline for knowledge transfer activities associated with research studies on boreal fire regimes.*

Advances in knowledge

Since the research studies were designed to assess the effectiveness of policy directions on emulating natural forest disturbances, the primary intent of advancing knowledge is to contribute to improving those policies. Therefore, the major outcome of the knowledge transfer activities described above will be advances in knowledge relating to MNR's NDPE guide (OMNR 2002) directions. As summarized in Table 5, the primary knowledge advances will be improved information about degrees of uncertainty in the guide's directions.

In addition, future forest management practices and policies will benefit from the knowledge generated through rigorous scientific methods. Clearly defining related uncertainties will contribute to improving the design of future forest policies and practices. In addition, understanding the underlying mechanisms and factors that cause variability in characteristics of fire disturbances will enable more effective planning for outcomes that will better emulate those disturbances. Finally, identifying the remaining uncertainties in scientific knowledge will clarify the limitations and defensibility of policies that are based on science.

From a science perspective, the main contributions will be improved understanding of the stochasticity of fire disturbances with respect to spatial, temporal, and random variability, as well as variability within and among fires. Repeatable and logical methods as well as explicit hypotheses will provide a basis for future research to ensure advancements in knowledge of boreal fire regimes continues.

Table 5. Advances in knowledge expected to result from each of the boreal fire regime study groupings in relation to policy guide directions, forest management practice, and science.

Study grouping	Advances in knowledge		
	NDPE guide	Forest management practices and policies	Science
Reviewing and synthesizing literature on boreal fire regimes and post-fire residuals	Uncertainties in directions with respect to natural fire size distribution, spatial proximity of fires, extent of residual patches and number of residual trees	• Clear state of knowledge of fire size distribution and post-fire residuals • Limitations of the present state of knowledge and problems with extrapolating research evidence for applications	• Known, uncertainties associated with known, and knowledge gaps • Weaknesses in methods and approaches of past research on fire size distribution and post-fire residuals • Focal areas for future research
Determining the characteristics of the broad-scale fire regime in boreal Ontario	Uncertainties in directions with respect to fire size distribution and spatial separation of forest fires	• Quantitative estimates of spatial, temporal, and random variability associated with fire occurrence, size and spatial patterns of fire events, and potential fire return interval • Estimate of regionality in potential fire regime and its variability under climate change assumptions • Uncertainty, variability, and reliability of present knowledge of forest succession	• Comparative assessment of fire simulation modelling methods • Methodology for simulating broad-scale forest landscape dynamics (fire and succession) in boreal forests • Explicit methodology for consolidating expert knowledge with research findings • Testable hypothesis for boreal forest fire regime characteristics and forest succession
Spatially characterizing aggregates of live tree residuals in unsuppressed boreal forest fires	Uncertainties in directions with respect to extent of insular and peninsular post-fire residual patches	• Quantitative estimates of extent, spatial patterns, and within- and among-fire variability in post-fire residual aggregates • Relative influence of spatial geometry of fire events, terrain, spatial patterns in water bodies and pre-burn cover composition, and other site factors on occurrence of post-fire residual aggregates	• Methodology for spatial pattern recognition and accuracy assessment with remotely sensed imagery • Testable hypotheses on formation, occurrence, spatial biases, and causal factors of post-fire residual aggregates
Characterizing abundance and spatio-temporal variability in residual stand structure in unsuppressed boreal forest fires	Uncertainties in directions with respect to number and spatial distribution of post-fire residual trees	• Quantitative estimates of extent, spatial patterns, and within- and among-fire variability in post-fire trees, snags, downed wood • Relative influence of fire behaviour, pre-burn cover composition, and site factors on occurrence of post-fire residual trees and snags • Quantitative estimates of temporal patterns in post-fire tree mortality and structural changes	• Assessment of errors associated with high-resolution photography in detecting post-fire residual structure • Testable hypotheses on causal factors of spatial biases and temporal trends in post-fire residual tree occurrence and mortality

Summary

A clear understanding of forest fire regimes is essential for emulating natural disturbances in forest management. We have developed a broad framework for a series of research studies to investigate Ontario boreal forest fire regime at multiple scales. The broad research goal is to reduce uncertainties in knowledge about boreal forest fire regimes to assess effectiveness of policy directions in MNR's NDPE guide (OMNR 2002). This goal is accomplished by (a) establishing the state of the knowledge by reviewing and synthesizing published literature, (b) determining the characteristics of the broad-scale fire regime in boreal Ontario through simulation modelling, and (c) understanding the extent and spatial patterns of post-fire residuals using mapping and monitoring. All studies adhere to rigorous scientific methods, but differ in approach. Study methods range from simulation modelling based on deductive reasoning to empirical studies based on inductive reasoning. Transfer of knowledge to key user groups is also an important consideration in study plans. Anticipated products include research papers and reports that capture study results and findings, new research methods and hypotheses, and multi-use spatial databases. In addition to reducing scientific uncertainties in NDPE guide directions, these studies will advance knowledge to inform future forest management policies and practices, as well as other research on forest fires and emulating natural disturbances.

For more information about study details, opportunities to collaborate, and forthcoming publications, contact the authors.

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Appendix I.

Action Plan for Scientific Studies to Assess the Effectiveness of the Directions in the Forest Management Guide for Natural Disturbance Pattern Emulation (ver. 3.1)

This document was prepared in response to Condition 39c of the Declaration Order (MNR-71) made under the *Environmental Assessment Act* regarding MNR's Class Environmental Assessment Approval for Forest Management on Crown Lands in Ontario. The Condition states that:

Within one year of this Declaration Order coming into force, MNR shall complete an action plan which shall describe scientific studies that shall assess the effectiveness of the direction for clearcut sizes, separation criteria for planned clearcuts, and standards for residual stand structure in MNR's approved forest management guide relating to the emulation of natural disturbance patterns, in providing for the emulation of natural disturbance patterns. The action plan shall include implementation schedules for these scientific studies.

This action plan was developed under terms of reference provided by MNR's EA Steering Committee (Attached).

The process for developing the action plan is outlined first, followed by the action plan (i.e., the list of scientific studies and their implementation schedule). This document concludes with a brief discussion of opportunities to transfer and implement the new knowledge gained from the proposed studies. An overview of the process is illustrated in Figure 1.

1. Developing the action plan

1.1 Scope of the task

- The Forest Management Guide for Natural Disturbance Pattern Emulation (NDPE Guide V3.1; 2001; hereafter referred to as the Guide) addresses emulation of stand-replacing fire disturbance patterns using the clearcut silvicultural system within boreal and Great Lakes-St. Lawrence forests. As required by Condition 39c, this action plan focuses on those areas in Ontario where stand-replacing fires and clearcut silviculture prevail (primarily the boreal forest). Its relevance to Great Lakes-St. Lawrence forests is limited to those areas where stand-replacing fires naturally occur. Studies assessing the Guide's direction for shelterwood silvicultural systems (i.e., non-stand replacing fires) are not included in this action plan.

- The goal of the Guide is to create forest landscapes that "resemble more closely the landscapes recently created naturally by fire ... with respect to the location and sizes of disturbances, residual stand structure, ...". The specific directions in the Guide are:
  (1) to create a more natural landscape pattern by planning harvest patterns to meet a specified (a) size-class distribution; and (b) patch separation distance;
  (2) to leave a more natural structural legacy by planning harvest patterns to leave a specified (a) residual patch area; and (b) number of residual trees.

- The effectiveness of the Guide can be assessed in two ways:
  (1) assessing the effectiveness of the Guide's directions (i.e., are the directions provided correct?) and
  (2) assessing the effectiveness of the outcome of the Guide's directions, having applied the directions correctly (i.e., were the expected results of applying the Guide achieved, assuming the Guide's directions were feasible to implement and applied correctly?).

- The goal of this action plan is to assess the effectiveness of the Guide's directions. It does not address the effectiveness of the Guide's outcome, which are expected to be addressed by other conditions of the Declaration Order, for example Condition 29 (silvicultural effectiveness monitoring) and Condition 31 (monitoring guide effectiveness).

- This action plan focuses on assessing the effectiveness of the Guide's directions from an ecological perspective; economic and social perspectives are beyond the scope of this exercise. This action plan provides a list of scientific studies to be pursued to verify the directions of the guide, providing details of the study goal, nature, participants, time frames, reporting procedures, proposed products, and anticipated new knowledge.

- Plans for implementing the study findings are beyond the scope of this exercise and therefore are not addressed in detail. Some possible options and expectations for transferring the knowledge gained from these proposed studies are briefly addressed in Section 3.

1.2 Identifying knowledge uncertainties and developing testable hypotheses

- Given the goal of the Guide, the effectiveness of the Guide's directions will be determined by the degree of similarity between natural fire patterns and the harvest patterns prescribed by the Guide. That is, how similar are the directions in the Guide to natural disturbance

patterns resulting from fire? Based on the EA Condition 39c, the Guide directions were separated into four criteria: clearcut size pattern, clearcut patch separation, residual patch area, and residual trees. The effectiveness of these criteria is assessed by their similarity to published knowledge on natural fire disturbances. If sufficient scientific evidence on natural fire disturbances relevant to the Guide's clearcut patch separation, residual patch area, and residual trees. The effectiveness of these criteria is assessed by their similarity to published knowledge on natural fire disturbances. If sufficient scientific evidence on natural fire disturbances relevant to the Guide's directions exists to support each criterion, then the associated knowledge uncertainty is low, and therefore those directions can be considered effective. Conversely, if scientific evidence on natural fire disturbances is scarce, inconsistent, or does not support the Guide's directions for a criterion, then the associated knowledge uncertainty is high. These directions are considered to require further scientific study, to verify their effectiveness.

- A preliminary literature review was used to identify the degree of knowledge uncertainty associated with each criterion, as explained above. The scientific literature on natural fire disturbances, including journal papers, books, graduate theses, and technical reports, was reviewed (over 1000 citations) and evaluated for direct evidence (support/refute) and strength of evidence (facts, hypotheses, no evidence) in relation to the ecological foundation for the four criteria (i.e., fire disturbance size patterns, fire disturbance patch separation, post-fire residual patch area, and post-fire residual trees).
- Based on the results of the literature review and with input from science experts, the knowledge uncertainties were converted into testable scientific hypotheses. Subsequently, a brief survey was conducted within the broader research community to examine whether these hypotheses are being studied in the boreal and Great Lakes-St. Lawrence regions in Canada and the United States. Four broad study groupings were developed to test the hypotheses that were not reported as being examined elsewhere. Several techniques (e.g., simulation modelling, literature reviews, historical fire analyses, and current fire surveys) are proposed to test these hypotheses. For each study group, the most appropriate methods for testing those hypotheses were chosen based on review of science literature, expert opinion, and feasibility. At least two research study techniques are proposed to assess each of the four criteria being examined.
- Information from the preliminary literature review will form an interim published product that is expected to contain an annotated bibliography, a synthesis of trends in the literature, and a register of related ongoing research studies.

2. Proposed scientific studies and implementation schedule

The following studies are proposed to assess the effectiveness of the directions in the Guide by improving the understanding of Ontario's natural fire regimes. For each of the four criteria, broad study groupings that comprise a series of sub-studies are provided. Studies are provided in pairs (for example, a simulation study and a survey of historical data for Criterion 2), the results of which supplement one another. Proposed literature reviews are intended to capture the state of broader scientific knowledge beyond what was used to develop the Guide. For each study, a goal statement, brief description of approach, contributors, time frame, and proposed products are listed. The expected knowledge is described by a series of examples, ranging from broad to specific, the latter relating to the Guide's directions.

2.1 Criterion 1: Landscape Harvest Patterns – Size Patterns

The current scientific knowledge (based on a preliminary review of published reports, books, and journal papers) on fire disturbance size patterns is limited and inconsistent. Therefore, the knowledge uncertainty about the size-class patterns in naturally occurring fire disturbances and associated directions for harvest size pattern in the Guide is considerable. The following studies are proposed to address these knowledge uncertainties.

Study 1 – Size patterns

Goal: To describe the naturally occurring fire disturbance patch size distribution and its variation in Ontario's fire-driven forest landscapes at eco-regional scale.

Study Approach: This study will consist of spatial simulation modelling of the forest fire regime in Ontario's boreal forest by eco-regions detailed in the Guide (3E, 3W, 3S, 4S, and portions of 4E). Great Lakes-St. Lawrence forests will be studied in eco-regions where stand-replacing fires prevail (4W, portions of 4E, 5E, and 5S). An Ontario-specific model will be used for these simulations.

OMNR Contributors:

- Applied Research and Development Branch – Forest Research and Development Section (Lead)
- Forest Management Branch – Forest Policy Section

Timeframe: Three years; beginning April 2005 and concluding April 2008

Reporting Procedures:

- Annual reporting of progress and interim findings to EA Condition steering committee and Provincial Forest Technical Committee

- Provincial Annual Report on Forest Management (as specified by Condition 39d)
- Five-Year EA (environmental assessment) Report (as specified by Condition 39e)

Proposed Products: In addition to updates in the Provincial Annual Report on Forest Management and Five-Year EA Reports, products are expected to include:

- New information on size-class distribution of fire disturbance patches at eco-regional scale to support Guide revision
- Final report on study findings

New Knowledge Expected: Upon completion of this study, new information is anticipated about the distribution of the natural fire disturbance patch sizes in Ontario's forests over time and in space, including:

- the likelihood of specific fire disturbance patch size classes; for example, what is the shape of the size-class distribution curve? Is 80% of the burned area within boreal fire disturbance patches less than 260 ha as per Guide directions for planned clearcuts?
- the variability of the likelihood of fire disturbance patch size classes among eco-regions; for example, does the shape of the size-class distribution curve change from eco-region to eco-region? If 80% of the burned area within boreal fire disturbance patches is less than 260 ha, is this true for all eco-regions as per Guide directions for planned clearcuts?
- the variability of the likelihood of fire disturbance patch size classes within eco-regions; for example, does the shape of the size-class distribution curve change within eco-regions? If 80% of the burned area within boreal fire disturbance patches is less than 260 ha, is this true everywhere within each eco-region as per Guide directions for planned clearcuts?
- the variability of the likelihood of fire disturbance patch sizes through time; for example, does the shape of the size-class distribution curve change through time? If 80% of the burned area within boreal fire disturbance patches is less than 260 ha, is this true through time as per Guide directions for planned clearcuts?

Study 2 – Size patterns

Goal: To understand Ontario's natural fire disturbance patch size distribution in the boreal forest biome in a broad North American context, as a supplement to Study 1.

Study Approach: This study will consist of a systematic analysis of the published literature related to fire disturbance patch size distribution in the boreal forest biome in North America.

OMNR Contributors:

- Applied Research and Development Branch – Forest Research and Development Section (Lead)
- Forest Management Branch – Forest Policy Section

Timeframe: One year; beginning April 2005 and ending April 2006

Reporting Procedures:

- Annual reporting of progress and interim findings to EA Condition steering committee and Provincial Forest Technical Committee
- Provincial Annual Report on Forest Management (as specified by Condition 39d)
- Five-Year EA (environmental assessment) Report (as specified by Condition 39e)

Proposed Products: In addition to updates in the Provincial Annual Report on Forest Management and Five-Year EA Reports, products are expected to include:

- Supplementary information on size-class distribution of fire disturbance patches to support Guide revision
- Report on literature review findings

New Knowledge Expected: Upon completion of this study, supplementary information is anticipated about the general trends in fire disturbance patch size distribution in the boreal forest biome across North America as found by other scientific studies to compare with findings from Ontario (e.g., Study 1).

2.2 Criterion 2: Landscape Harvest Patterns – Patch Separation

The current scientific knowledge (based on a preliminary review of published reports, books, and journal papers) on fire disturbance patch separation is non-existent. Therefore, the knowledge uncertainty about the patch separation patterns in naturally occurring fire disturbances and associated directions for patch separation in the Guide is extremely high. The following studies are proposed to address this knowledge uncertainty.

Study 3 – Patch separation

Goal: To describe the spatial pattern of fire disturbance patches that could potentially occur naturally at landscape scale and its variation.

Study Approach: This study will consist of spatial simulation modelling of the forest fire regime in Ontario's boreal forest by eco-regions detailed in the Guide (3E, 3W, 3S, 4S, and portions of 4E). Great Lakes-St. Lawrence forest will be studied where stand-replacing fires prevail (4W, portions of 4E, 5E, and 5S), focusing on the landscape-scale (within each eco-region) patterns of fire disturbance patch occurrence. An Ontario-specific model will be used for these simulations.

OMNR Contributors:

- Applied Research and Development Branch – Forest Research and Development Section (Lead)
- Forest Management Branch – Forest Policy Section

Timeframe: Three years; beginning April 2005 and ending April 2008

Reporting Procedures:

- Annual reporting of progress and interim findings to EA Condition steering committee and Provincial Forest Technical Committee
- Provincial Annual Report on Forest Management (as specified by Condition 39d)
- Five-Year EA (environmental assessment) Report (as specified by Condition 39e)

Proposed Products: In addition to updates in the Provincial Annual Report on Forest Management and Five-Year EA Reports, products are expected to include:

- New information on spatial patterns in the potential occurrence of fire disturbance patches at eco-regional scale to support Guide revision
- Final report on study findings

New Knowledge Expected: Upon completion of this study, new information is anticipated about the potential patterns in spatial occurrence of fire disturbance patches in fire-driven forest landscapes, including:

- the local spatial biases in the size-class distribution of fire disturbance; for example, is the chance of occurrence of large fire disturbance patches equal across a landscape, or are they more/less likely to occur in some parts?
- the likelihood of fire disturbance patches overlapping in time and space; for example, what is the likelihood of two adjacent fire disturbance patches merging? How long does it take for fire disturbance patches to merge in space? How is this likelihood influenced by local site factors?
- the likelihood of fire disturbance patch proximity; for example, are smaller patches likely to be closer to one another than larger patches? Are fire disturbance patches always minimally 200 m apart as per Guide directions? Is the distance between fire disturbance patches directly proportional to their size, increasing at a rate of 50 m per 100 ha as per Guide directions?

Study 4 – Patch separation

Goal: To describe the spatial pattern of fire disturbance patches that did occur naturally at landscape scale in boreal Ontario.

Study Approach: This study will analyze a series of historical fire data collected from areas in Ontario where fires have not been suppressed (fire suppression affects size and shape of fires and therefore their spatial pattern).

OMNR Contributors:

- Applied Research and Development Branch – Forest Research and Development Section (Lead)
- Science and Information Branch – Regional Science and Information Sections
- Forest Management Branch – Forest Policy Section

Timeframe: Three years; beginning April 2005 and ending April 2008

Reporting Procedures:

- Annual reporting of progress and interim findings to EA Condition steering committee and Provincial Forest Technical Committee
- Provincial Annual Report on Forest Management (as specified by Condition 39d)
- Five-Year EA (environmental assessment) Report (as specified by Condition 39e)

Proposed Products: In addition to updates in the Provincial Annual Report on Forest Management and Five-Year EA Reports, products are expected to include:

- New information on spatial patterns of historical fire disturbance patches to support Guide revision
- Final report on study findings

New Knowledge Expected: Upon completion of the study, additional information is anticipated on spatial patterns of (unsuppressed) fire disturbance patches that occurred in various parts of Ontario to extend the understanding gained in the simulation study (i.e., Study 3), including:

- the local spatial biases in the size-class distribution of fire disturbance; for example, is the chance of occurrence of large fire disturbance patches equal across a landscape, or are they more/less likely to occur in some parts?
- the likelihood of fire disturbance patches overlapping in time and space; for example, what is the likelihood of two adjacent fire disturbance patches merging? How long does it take for fire disturbance patches to merge in space? How is this likelihood influenced by local site factors?
- the likelihood of fire disturbance patch proximity; for example, are smaller patches likely to be closer to one another than larger patches? Are fire disturbance patches always minimally 200 m apart? Is the distance between patches directly proportional to their size, increasing at a rate of 50 m per 100 ha as per Guide directions?
- additional information will be generated from analyses of current fire patterns (see Study 5)

2.3 Criterion 3: Structural Legacy: Residual Stands

The current scientific knowledge (based on a preliminary review of published reports, books, and journal papers) on post-fire residual stands is sparse and inconsistent. Therefore, the knowledge uncertainty about the residual stand patterns in naturally occurring fire disturbances and associated directions for residual stands in the Guide is high. The following studies are proposed to address this knowledge uncertainty.

Study 5 – Residual patches

Goal: To describe the spatial and temporal patterns of within post-fire disturbance patch residual stands and its variation in Ontario's fire-driven forest landscapes within eco-regions and within landscapes.

Study Approach: This study will analyze a series of current unsuppressed fire disturbance patches of various sizes and locations that represent the variation in landscapes, using large-scale photography and other spatial databases.

OMNR Contributors:

- Applied Research and Development Branch – Forest Research and Development Section (Lead)
- Science and Information Branch – Forest Resource Inventory Unit
- Forest Management Branch – Forest Policy Section

Timeframe: Three years; beginning April 2005 and ending April 2008

Reporting Procedures:

- Annual reporting of progress and interim findings to EA Condition steering committee and Provincial Forest Technical Committee
- Provincial Annual Report on Forest Management (as specified by Condition 39d)
- Five-Year EA (environmental assessment) Report (as specified by Condition 39e)

Proposed Products: In addition to updates in the Provincial Annual Report on Forest Management and Five-Year EA Reports, products are expected to include:

- New information on spatial patterns of residual stands within fire disturbance patches to support Guide revision
- Final report on study findings

New Knowledge Expected: Upon completion of the study, new information is anticipated about patterns of insular and peninsular residual stands (within post-fire disturbance patches) and their variation through time and in space, including:

- the extent of post-fire residual area, in peninsular and insular categories, and causal factors of their variability; for example, does the peninsular residual area range from 8 - 28% and does the insular area range from 2 - 8% as per Guide directions? Is this independent of fire disturbance patch size? What influence do forest type and micro-geoclimatic factors (e.g., ecosite) exert?
- the spatial distribution of residual stands within a fire disturbance; for example, are peninsular and insular areas more likely to occur on certain site features within fire disturbances?
- the size-class distribution of residual stands; for example, are 20% < 5 ha, 35% 5 - 50 ha and 45% > 50 ha as per Guide directions? Is this independent of fire disturbance patch size, forest type, and micro-geoclimatic features?
- re-burn patterns of residual stands; for example, what is the likelihood of residual stands burning within 20 years, and does this depend on the forest type and site features? (information from historical fire study -- see patch separation above)
- temporal changes to residual stands; for example, what is the likelihood of residual stands changing structure and composition within 20 years, and does this depend on the forest type and site features? (information from historical fire study -- see patch separation above)

Study 6 – Residual stands

Goal: To understand Ontario's spatial patterns of within post-fire disturbance patch residual stands and its variation in fire-driven forest landscapes within eco-regions in a broad North American context, as a supplement to Study 5.

Study Approach: This study will consist of a systematic analysis of the published literature related to post-fire residual stands in the boreal forest biome in North America.

OMNR Contributors:

- Applied Research and Development Branch – Forest Research and Development Section (Lead)
- Forest Management Branch – Forest Policy Section

Timeframe: One year; beginning April 2005 and ending April 2006

Reporting Procedures:

- Annual reporting of progress and interim findings to EA Condition steering committee and Provincial Forest Technical Committee
- Provincial Annual Report on Forest Management (as specified by Condition 39d)
- Five-Year EA (environmental assessment) Report (as specified by Condition 39e)

Proposed Products: In addition to updates in the Provincial Annual Report on Forest Management and Five-Year EA Reports, products are expected to include:

- New information on spatial patterns of residual stands within post-fire disturbance patches to support Guide revision
- Publishable report on literature review findings

New Knowledge Expected: Upon completion of this study, supplementary information is anticipated on general patterns in the occurrence and distribution of post-fire residual stands in the boreal forest biome across North America as found by other scientific studies to compare with findings from Ontario (e.g., Study 5).

2.4 Criterion 4: Structural Legacy: Residual Trees and Downed Woody Debris

The current scientific knowledge (based on a preliminary review of published reports, books, and journal papers) on post-fire disturbance residual live trees, snag trees, and downed woody debris exists but is highly inconsistent. Therefore, the knowledge uncertainty about the residual tree patterns and downed woody debris in naturally occurring fire disturbances and associated directions in the Guide is high. The following studies are proposed to better understand this knowledge uncertainty.

Study 7 – Residual Trees and Downed Woody Debris

Goal: To describe the spatial and temporal patterns of within post-fire disturbance patch residual live tree, snag tree, and downed woody debris abundance and distribution and its variation in Ontario's fire-driven forest landscapes.

Study Approach: This study will consist of post-fire field surveys conducted immediately after fire, preferably unsuppressed, and analysis of this information in relation to other spatial data.

OMNR Contributors:

- Applied Research and Development Branch – Forest Research and Development Section (Lead)
- Science and Information Branch – Regional Science and Information Sections
- Northeast, Northwest and Southern Region – Districts and Areas
- Forest Management Branch – Forest Policy Section

Timeframe: Three years; beginning April 2005 and ending April 2008

Reporting Procedures:

- Annual reporting of progress and interim findings to EA Condition steering committee and Provincial Forest Technical Committee
- Provincial Annual Report on Forest Management (as specified by Condition 39d)
- Five-Year EA (environmental assessment) Report (as specified by Condition 39e)

Proposed Products: In addition to updates in the Provincial Annual Report on Forest Management and Five-Year EA Reports, products are expected to include:

- New information on residual live tree, snag tree, and downed woody debris abundance and distribution in post-fire disturbance patches to support Guide revision
- Final report on study findings

New Knowledge Expected: Upon completion of the study, new information is anticipated about patterns of live tree, snag tree, and downed woody debris occurrence and distribution over time and in space within post-fire disturbance patches and its variability, including:

- temporal changes to the number of live residual and snags trees within a fire disturbance patch and its variation; for example, how long do live residual and snag trees remain standing following burns? Is this independent of species, size, and micro-geoclimatic factors?
- amount of downed woody debris within a fire disturbance patch and its variation; for example, is the amount of downed woody debris independent of fire size, forest type, and micro-geoclimatic factors?

Study 8 – Residual Trees and Downed Woody Debris

Goals: To understand the spatial patterns of within post-fire disturbance patch live tree, snag tree, and downed woody debris abundance and distribution, and its variation in fire-driven forest landscapes in a broad North American context, as a supplement to Study 7.

Study Approach: This study will consist of a systematic analysis of the published literature related to within post-fire disturbance patch live tree, snag tree, and downed woody debris abundance in the boreal forest biome in North America.

OMNR Contributors:

- Applied Research and Development Branch – Forest Research and Development Section (Lead)
- Science and Information Branch – Regional Science and Information Sections
- Forest Management Branch – Forest Policy Section

Timeframe: One year; beginning April 2005 and ending April 2006

Reporting Procedures:

- Annual reporting of progress and interim findings to EA Condition steering committee and Provincial Forest Technical Committee
- Provincial Annual Report on Forest Management (as specified by Condition 39d)
- Five-Year EA (environmental assessment) Report (as specified by Condition 39e)

Proposed Products: In addition to updates in the Provincial Annual Report on Forest Management and Five-Year EA Reports, products are expected to include:

- New information on live tree, snag tree, and downed woody debris abundance and distribution in post-fire disturbance patches to support Guide revision
- Publishable report on literature review findings

New Knowledge Expected: Upon completion of this study, supplementary information is anticipated about the general patterns in the occurrence and distribution of within post-fire disturbance patch live tree, snag tree, and downed woody debris abundance in the boreal forest biome across North America as found by other scientific studies to compare with findings from Ontario (e.g., Study 7).

3. Communications and Knowledge Transfer

The results of these studies, when available, are expected to contribute to the development of the new Landscape Guide and other appropriate forest management guides, as well as subsequent revisions to those documents. Periodic updates provided to the Provincial Forest Technical Committee, in Provincial Annual Reports and Five-Year EA Reports will ensure awareness of study progress and provide information about where study findings are documented for use in current and future guide revisions.

Results of some of these studies (i.e., Study 1, 3, 4, 5 and 7) are expected to contribute to the scientific literature. A review paper synthesizing the state of knowledge of natural fire disturbance pertaining to directions in the Guide is also expected to add to the broader scientific literature.

Summary

The Forest Management Guide for Natural Disturbance Pattern Emulation provides guidance for emulating fire patterns using landscape harvest patterns and structural legacy; as captured by specific directions about clearcut size patterns, separation criteria for planned cuts, residual patches, and residual trees. The ecological foundation for these directions was examined by reviewing the published knowledge on fire disturbance patterns. In doing so, the degree of knowledge uncertainty associated with the directions was determined, and relevant scientific questions formulated to reduce these knowledge uncertainties. The broad scientific study groups proposed in this action plan address these questions with the intent of developing new and reliable knowledge related to the four directions at a nested hierarchy of spatial scales, within a three-year period beginning in April 2005 and ending in April 2008. Several periodic reporting mechanisms will ensure that the progress of scientific studies is monitored and new knowledge is made available for future guide revisions. Figure 1 provides an overview of the development and details of the action plan.

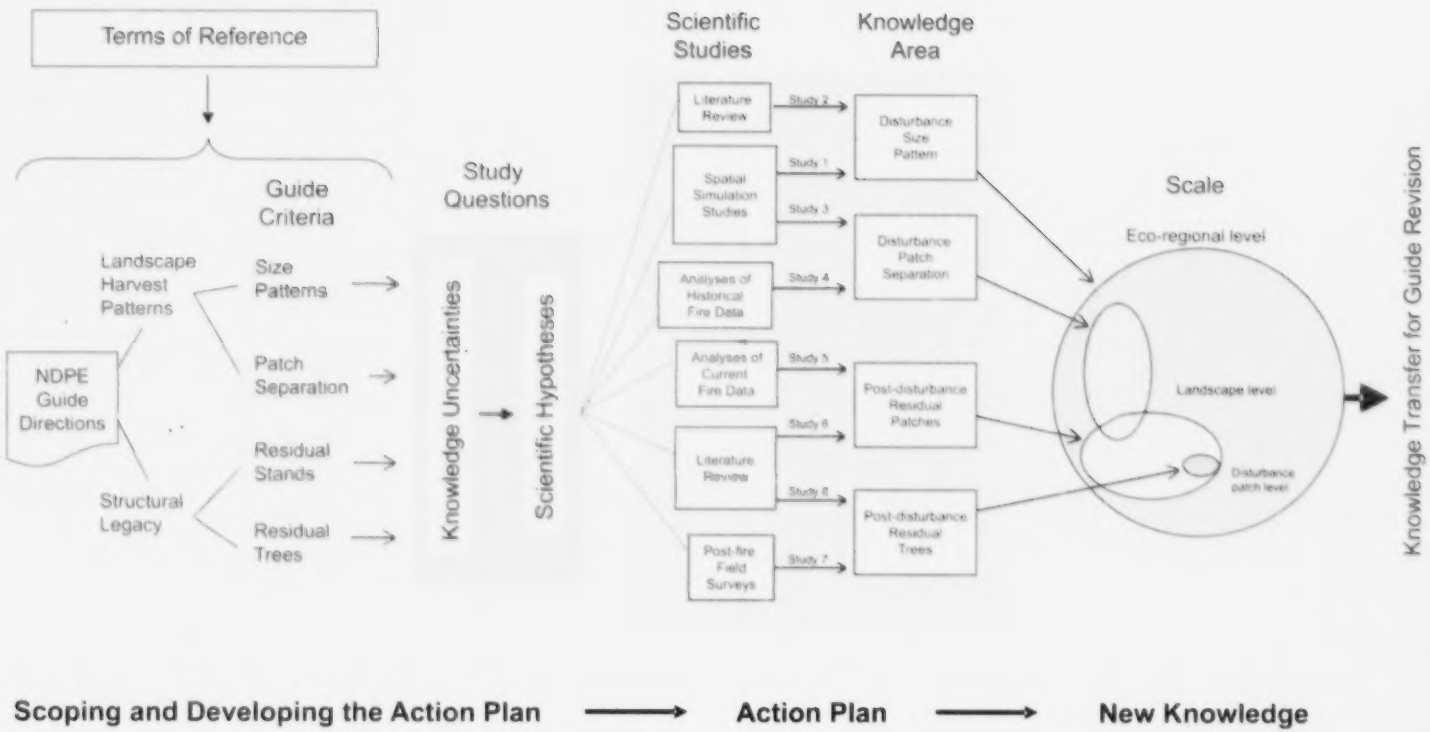

Figure 1. *Schematic overview of the development and details of the action plan for scientific studies to assess the effectiveness of the Guide.Appendix 1. Terms of Reference for Developing EA Condition 39c Action Plan (Feb 13, 2004)*

Terms of Reference for Developing EA Condition 39c Action Plan (Feb 13, 2004)

Background

The Action Plan for Condition 39c will address specific requirements in the wording of the condition contained in the declaration order as follows:

"Within one year of this Declaration Order coming into force, MNR shall complete an action plan which shall describe scientific studies that shall assess the effectiveness of the direction for clearcut sizes, separation criteria for planned clearcuts, and standards for residual stand structure in MNR's approved forest management guide relating to the emulation of natural disturbance patterns, in providing for the emulation of natural disturbance patterns. The action plan shall include implementation schedules for these scientific studies".

Criteria for addressing effectiveness of the direction defined above will consider the purpose, objectives, and embedded assumptions contained in the Forest Management Guide for Natural Disturbance Pattern EmulationV3.1 (OMNR 2001).

Appropriate understanding of the other relevant science-related EA conditions (29, 30, 31, 38, 42, and 45) and their implementation plans is required for context, and identifying gaps and redundancies.

Goal

This action plan will focus on the specific direction provided in Condition 39c, not the broader need to monitor the overall effectiveness of the NDPE guide, which should be addressed by Conditions 29 (silvicultural effectiveness monitoring), 31 (effectiveness monitoring of guides), and 38 (development of landscape guide).

The goal is to develop an action plan that identifies the ecological knowledge uncertainties associated with emulating natural disturbances, specifically the effectiveness of the direction for clearcut sizes, separation criteria for planned clearcuts, and standards for residual stand structure in the NDPE guide, in creating more natural landscape patterns (the stated goal of the guide).

Effective here means how closely the criteria specified in the guide create patterns that resemble those created by natural disturbances (specifically by fire).

Deliverable

The product will be an action plan that will include a list of scientific studies to address above ecological uncertainties (not social or economic) with a proposed implementation schedule. This plan will be delivered for internal MNR review by May 15, with the final version ready for submission to MOE by June 25, 2004.

This action plan will contain the following:

- goals and objectives
- questions to be addressed
- description of activities
- implementation schedule
- roles and responsibilities for implementation
- expected accomplishments and outcome of the action plan.

It may include appendices that will provide additional details. It will be written for public consumption with minimal technical jargon and details.

Project Team

Ajith Perera and Lisa Buse

Steering Committee

The project team will report to the Steering Committee (Ed Iwachewski, Joe Kapron, and Brian Hillier). Joe Churcher, Laurie Mace, Michael Gluck and Jim Baker will act as advisors to the project team.

Appendix II.

Study advisory team members for each research area and overall.

Advisor	Affiliation	Overall	Spatial simulation modelling	Post-fire residual aggregates	Post-fire residual structure
David Andison	Foothills Model Forest			X	X
Jim Baker	ARDB, MNR	X			
Den Boychuk	AFFMB, MNR	X	X		
Mike Briennesse	FMB, MNR			X	X
Joe Churcher	FMB, MNR	X			
Phil Elkie	SIB, MNR			X	X
Wayne Fiset	ARDB, MNR	X			
Michael Gluck	FMB, MNR	X	X		
Robert Janser	AFFMB, MNR				X
Greg Lucking	NER, MNR				X
Doug McRae	CFS			X	X
Mark Parsons	ARDB, MNR	X			
Kevin Ride	NWR, MNR		X		
Roger Suffling	Univ. Waterloo	X		X	
Ian Thompson	CFS	X			X
Al Tithecott	AFFMB, MNR			X	
Stan Vasiliauskas	SIB, MNR		X		
Mike Wotton	CFS		X		

* ARDB – Applied Research and Development Branch; AFFMB – Aviation and Forest Fire Management Branch; CFS – Canadian Forest Service – Great Lakes Forestry Centre; FMB – Forest Management Branch; MNR – Ministry of Natural Resources; NER – Northeast Region; NWR – Northwest Region; SIB – Science and Information Branch; Univ. -- university

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